# FINER POINTS

"The ONLY magazine dedicated solely to the technology and application of superabrasives."

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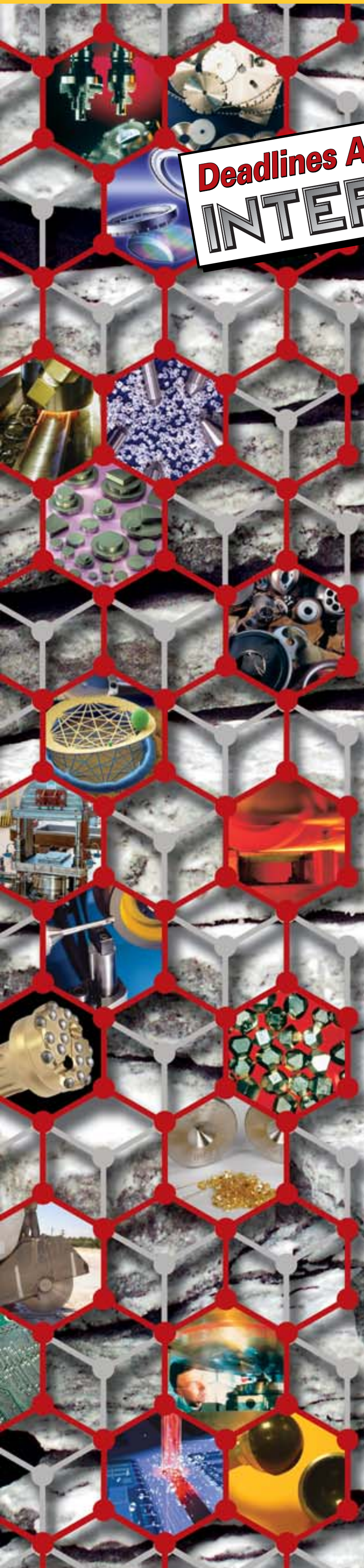

Using Orientation Imaging Microscopy To Measure Particle Size Of Sintered Polycrystalline Diamond

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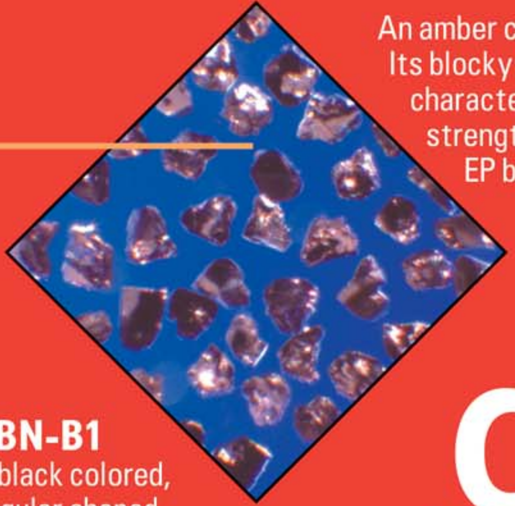
PCD Inserts for Improved Hard Rock Mining Efficiency

Development Of New PDC Material And Evaluation Of Properties

# Cubic Boron Nitride



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*"The ONLY magazine dedicated solely to the technology and application of superabrasives."*

## feature articles

9 **Using Orientation Imaging Microscopy To Measure Particle Size Of Sintered Polycrystalline Diamond**

16 **INTERTECH 2008 Information & FINAL Call For Papers**

18 **PCD Inserts for Improved Hard Rock Mining Efficiency**

24 **Development Of New PDC Material And Evaluation Of Properties**

## departments

4 **A Finer Point of View**

6 **Editorial**

8 **News & Notes**

11 **Membership Application**

12 **Calendar of Events**

14 **Announcements & Products**

29 **Ad Insertion Rates**

30 **Checklist of Things To Do …**

***FINER POINTS*** is the only publication devoted exclusively to the understanding, selection and application of diamond, cubic boron nitride and related materials. It is edited for recipients who are involved in some way with these "superabrasives", either as providers of the materials, producers of products containing the materials or users of these products (e.g., grinding wheels, dressing tools, drill bits, saw blades, sawing wires, cutting tools, polishing compounds, CVD film products, etc.).

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Worldwide Superabrasives LLC ........ 7

***COVER PHOTO***

Rock Bits courtesy of Smith Megadiamond.

# A Finer Point of View…

**PRESIDENT**
David Simpson

Think outside the box… Ever hear that one before? I'll bet you have and in its pure sense it means don't be stuck in doing what you do every day or the same thing over and over by staying in the "box". Instead, use your imagination to see beyond the ordinary and accepted practices to be original with a new idea. As we review abstracts that have been submitted for INTERTECH 2008 I am struck by the fact that they are not only new ideas, but ideas that have been rethought to present established data in a new way. Too many times we hear people in this industry say, "I've heard that before", or "we worked on that back in 1980". That mindset sometimes keeps new ideas from flourishing. I remember hearing a story that a certain product called cubic boron nitride was invented in 1957 to be a replacement for diamond. When the new product was subjected to all the tests normally applied to diamond it proved not as hard as diamond and in fact had other properties not as impressive as diamond. When it fell short in all the diamond tests it was placed on a shelf and all but forgotten. According to its inventor it was an invention without an application. Then in the early 70's it was found that cubic boron nitride was excellent for grinding hard steels and nickel-based alloys, for which diamond isn't cost-effective. This has led to a multi-million dollar industrial technology to manufacture high-precision steel and other alloy parts and to sharpen high-speed steel tools. What products today are still out there waiting for that extra boost to be the cBN of tomorrow? Will it be Aggregated diamond nanorods, Fullerites, CVD cBN or some other material still being researched for that economic production leap or revolutionary application? At the Industrial Diamond Association we are routinely fielding inquiries regarding "new materials" or materials harder than diamond or cubic boron nitride. It goes without saying that many of these inventers feel they have created some Earth-shaking product, but many times their efforts are lacking that one big breakthrough to create a repeatable and cost effective process. Over the past few INTERTECH conferences we have had the opportunity and great experience to hear about new materials still in the research stages. Many of these have come from Government sponsored research facilities as well as dedicated academic intellectuals. Some are just on the edge of a breakthrough and others just keep us facinated with reports and experiments of increasing successes. Yes, that diamond that filtered blood in the Ukraine, new PDC in Korea, bonding alloy from Germany, or that diamond diode in China will keep us all coming back and pique our interest. Personaly I can't wait to hear Dr. Jeffery Taylor speak on all the fantastic medical breakthroughs in diamond joints for the human body, James Campbell of Pratt & Whitney talk about new materials for superabrasive processes in aerospace and who would miss Dr. Post, curator of the gems and minerals from the Smithsonian Institute … In May, you don't want to miss INTERTECH 2008 either… and take that opportunity to be "outside the box"!

Sincerely,

David Simpson

David Simpson, President
Industrial Diamond Association of America

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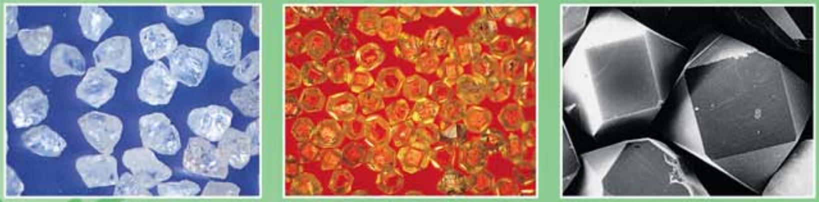

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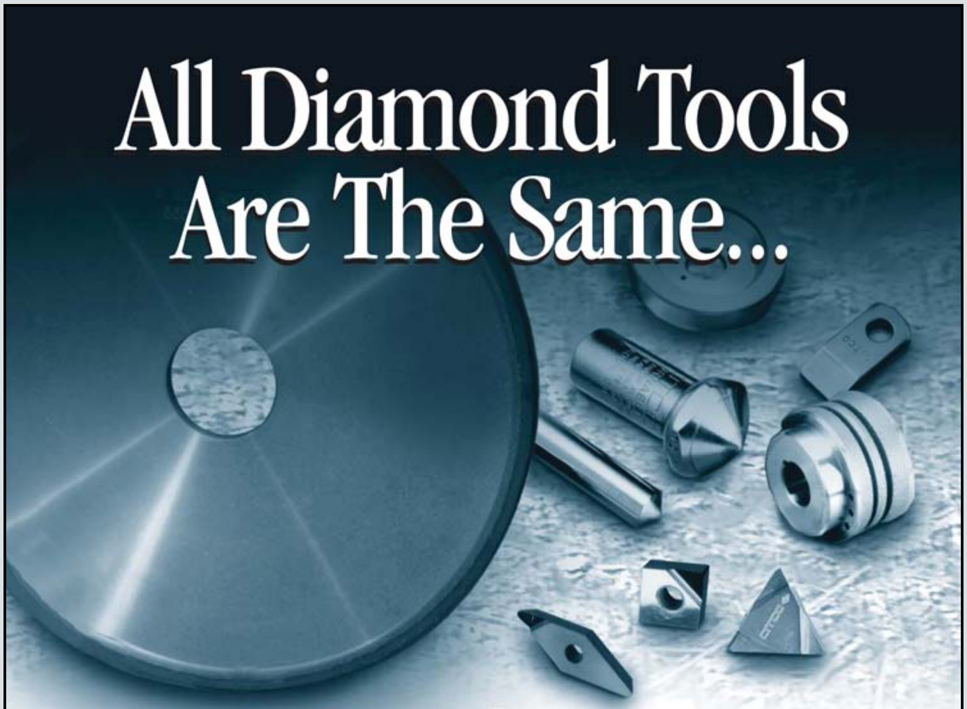
# Editorial

**TERRY KANE, Editor**

## Going Green with Envy

Almost forty years ago, a certain celebrity named Kermit the Frog first sang the melancholy tune *"It's Not Easy Being Green"*, bemoaning his color. Today, many organizations have taken this simple song and made it the anthem for *"Being Green"* in the environmental sense. The concern for global warming has taken center stage as melting polar caps and the plight of animals, like the polar bear, are a crisis. This tragedy may have been overlooked for years, but the reality is now upon us and directly related to Global warming, the *increase* in the greenhouse effect that warms the Earth's surface. Global warming is believed to be the result of increased concentrations of greenhouse gases in the atmosphere. Science, business, and government organizations support the fact that reducing greenhouse gas is an inevitable and integral component of doing business. Environmental awareness, particularly excess greenhouse gases, has seen a surge of visibility from the international and domestic business communities. The majority of greenhouse gases come from natural sources but human activity is a major contributor. Thus, businesses worldwide are turning their focus to increased environmental awareness through reduction of resource consumption, particularly of fossil fuels, which is the leading cause of excess greenhouse gases. In our own industry we have been aware for years of the need to cut back on energy consumption through cutbacks in the use of power for making diamond to the lighting and heating of our manufacturing facilities. It takes a lot of power to make diamond and most companies have used extraordinary measures to improve productivity and reduce the overall use of energy. Of course, the very application of superabrasives helps to improve manufacturing processes by reducing scrap, providing lower energy costs for end users and helping eliminate conventional abrasives like aluminum oxide that contribute to hazardous waste and disposal. The hardest part of our job may be to educate the end user to make the switch and convert to superabrasives and energy efficient machine tools. Internationally almost every country is addressing the concerns of a greener planet from global warming and carbon emissions to recycling and reusing critical materials. The green cause is trumpeted from China to The Netherlands and India to Australia. It's not just governments and major companies, but the individual person who must shoulder the effort and accountability. The other day I was looking up some data and came across a website called "Green IQ". On this site there is a survey to evaluate our environmental conscience. There are simple items that everyone can do to reduce energy costs and resource consumption, particularly of fossil fuels. The list is long and eye opening… sharing a ride, fresh foods, eco-friendly clothes, fluorescent lights, recycling, heating/cooling temps and many others. How about email faxes or using both sides of fax paper? Going green in the early days was looked at as the latest fad, but as we become smarter and more conscientious, we are all realizing the day is upon us when we will be constrained by government regulations and restrictions, but more importantly our customers and peers will start asking *are we a good neighbor and environmentally conscious?* Kermit did say it best in 1970, *"Green can be important like a river, big like a mountain or tall like a tree"*…



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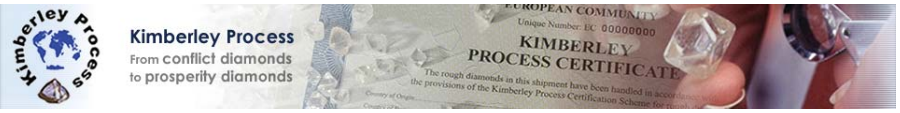
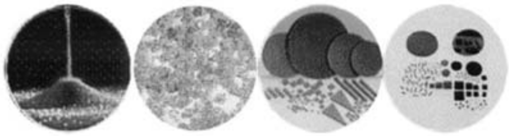
# NEWS and notes



**KIMBERLEY PROCESS HAS ISSUED A NEW DIRECTIVE FOR THE DIAMOND INDUSTRY.** The Clean Diamond Trade Act (the "Act"; Public Law 108-19) was signed into law on July 29, 2003. Act prohibits the "importation into, or exportation from, the United States on or after July 30, 2003, of any rough diamond, from whatever source, unless the rough diamond has been controlled through the Kimberly Process Certification Scheme (KPCS)". The Census Bureau is responsible for collecting, compiling and publishing import and export statistics for the U.S. under the provisions of Title 13 and Title 15 U.S.C. The Act requires the Census Bureau to maintain statistics on imports and exports of rough diamonds under subheadings 7102.10, 7102.21, and 7102.31 of the Harmonized Tariff Schedule of the United States. All importers of rough diamonds must fax a copy of their KPC certificates to the Census Bureau upon making entry with U.S. Customs and Border Protection. Copies of the KPC must be faxed to 1-800-457-7328. Questions regarding the KPCS may be directed to Ms. Adria Gibson at 202-863-6057.



**ILJIN DIAMOND IS WORKING ON A "DREAM MATERIAL" TO REPLACE THE LCD CORE PART.** Composed of hexagon-shaped with the diameter of a nanometer (a billionth m) it has high electroconduction and strength and is widely favored as a next-generation material by several huge companies. Iljin is conducting the final tests for the commercialization of CNT, and plan to release a prototype next July and begin mass production next yearend. "CNT is 20~30% cheaper than the existing fluorescent material and mercury containing materials, which will be restricted in the long run for environmental reasons. For more information visit: https://www.iljin.co.kr/eng/PRCenter/medialljin.asp

**DECEMBER 2007 CSDA ADDS 21 COURSES TO ONLINE TRAINING WEBSITE.** St. Petersburg, FL – The Concrete Sawing and Drilling Association, which earlier this introduced a new online training website, is pleased to announce that it has added 21 new online training courses. The new courses, covering health and safety and business subjects, were made available through CSDA's partnership with ProTraining.com. These courses supplement the very popular five initial courses that covered flat sawing, wall sawing, core drilling, hand sawing and wire sawing. "Participation in the online training programs has exceeded our expectations since the site was established earlier in 2007," said Patrick O'Brien, Executive Director. "The 700 completed courses represent 50 percent of the total number of courses for the classroom training courses that began in 1993. The addition of new courses will quickly make the online training courses the top training resource for CSDA." Contact: Patrick O'Brien, Executive Director Concrete Sawing & Drilling Association pat@csda.org.

**NEW WHITE PAPER DETAILS FUME COLLECTION SOLUTIONS FOR HEXAVALENT CHROMIUM EXPOSURE.** Cincinnati, OH - A new white paper from the United Air Specialists provides specific guidance on how to comply with OSHA specifications on hexavalent chromium and minimize harmful exposure through air filtration. Hexavalent chromium (CrVI) compounds are used as corrosion inhibitors and present an occupational hazard to workers that weld, torch cut or grind chromium-containing metals such as stainless steel. Exposure to hexavalent chromium through inhalation or touch can pose significant health risks to workers, including lung cancer, skin and membrane ulcerations, allergies and skin irritation. The white paper is entitled "Fume Collection Solutions for Hexavalent Chromium Exposure", a PDF file can be downloaded from United Air Specialists: www.uasinc.com.

**DECEMBER 2007 RAW MATERIAL AND ENERGY COSTS ARE BIGGEST THREATS TO PRIVATE MANUFACTURING BUSINESSES.** Grant Thornton International Business Report on manufacturing that privately held manufacturers across the world are being impacted greatest by the rising costs of raw materials and energy. Research from Grant Thornton International shows that the increasing costs of raw materials and energy are having major impacts on cost pressures for privately held manufacturers. Globally, 61% of surveyed businesses reported being most concerned about raw materials costs and 45 % reported energy costs. Turkish manufacturing businesses are the most concerned about energy costs in the next 12 months with 82% of respondents expecting these to have a major impact on cost pressures. Despite being a major oil producing country, 61% of manufacturers in Mexico cite energy costs as a concern. Australia and Brazil, also energy producing countries, are least concerned about energy costs, with 20% and 23% expecting them to have major impact. The management of energy consumption is key to tackling global warming - reduction in costs is the result. Two thirds of manufacturers reported taking measures to reduce their energy consumption. They reported installing energy saving lighting, motion detectors, insulation and measures to ensure that IT equipment is turned off while not in use to cut down on usage and costs. Over half of responding manufacturing businesses are investing in energy saving plant and machinery. For further information please contact: Kristi Grgeta at Grant Thornton International Limited kristi.grgeta@gt.com

# Using Orientation Imaging Microscopy To Measure Particle Size Of Sintered Polycrystalline Diamond

By: DANNY LaDUE – US Synthetic and
MATT NOWELL – EDAX - TSL

***Orientation Imaging Microscopy (OIM) is used to measure grain size and particle size distribution of sintered polycrystalline diamond (PCD). Traditional methods of measuring grain size are tedious and inaccurate. By utilizing OIM, the measuring of PCD grain size becomes accurate and efficient. The technique is able to assign single orientation to each diamond grain, eliminating the common error encountered when sintered grain boundaries are difficult to identify. This method of PCD grain size measurement provides immediate benefits in analyzing the durability qualities of PDC and may provide future benefits in designing new and more durable PDC.***

## POLYCRYSTALLINE GRAIN SIZE CRITICAL TO PERFORMANCE OF CUTTERS

Polycrystalline Diamond Compacts (PDC) are used as the cutting structure in "fixed cutter" oil and gas well drilling bits (Photo 1). PDC is manufactured by sintering diamond powder on tungsten carbide substrates at high temperature and pressure. Two of the important performance characteristics of PDC, wear resistance and impact resistance, can be influenced by manipulating polycrystalline diamond (PCD) grain size. Previous methods of grain size evaluation, including light and scanning electron microscopes, are effective but tedious. Orientation Imaging Microscopy (OIM) utilizes automated electron backscattered diffraction (EBSD) and provides a new way to analyze the particle size of PCD.

## EXPERIMENTAL SPECIMEN PREPARATION

The samples used in this analysis were typical production polycrystalline diamond cutters. Samples were sectioned and compression mounted in phenolic. Two methods of sample polishing were utilized. The first was a typical metallurgical polishing procedure utilizing sequentially smaller sizes of polishing diamond in suspension. This method creates a mirror finish (Photo 2) on the tungsten carbide substrate but not on the diamond table. The second technique utilizes a resin bond polishing wheel that provides a mirror finish on the diamond table, but prevents any examination of the tungsten carbide substrate. OIM does require a smooth surface finish, and the resin bond diamond wheel polishing process was found to be preferable for EBSD.

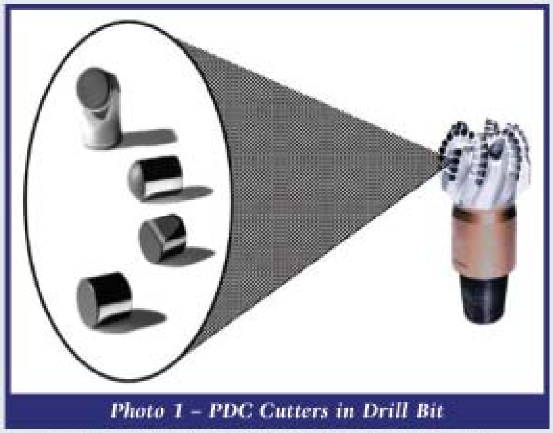


*Photo 1 – PDC Cutters in Drill Bit*

## CAPTURING THE SAMPLE'S CRYSTAL ORIENTATION INFORMATION

OIM is a technique used in scanning electron microscopes (SEM) and is based on EBSD. EBSD patterns are generated when the SEM's electron beam interacts with the crystalline lattice of the sample. A pattern is generated by this interaction, and the bands in the pattern (Kikuchi bands) describe planes in the crystal lattice. The geometrical arrangements of the bands are a function of the orientation of the diffraction crystal lattice. By indexing and automating the generation and collection of these patterns, OIM captures the sample's crystal orientation information.

## OIM ANALYSIS

EDAX-TSL in Draper, UT, manufactures and sells OIM equipment and software. The analysis of the PDC samples described below occurred at their laboratory. For this analysis, an 180μm x 180μm area was examined with a step size of

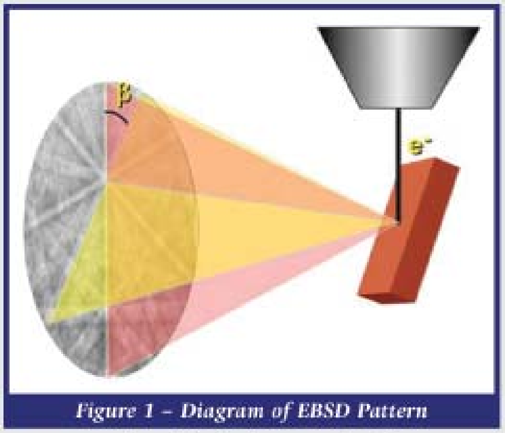


*Figure 1 – Diagram of EBSD Pattern*

0.25µm. The typical EBSD patterns generated from the resin bond diamond wheel polished PCD are shown in Photos 3 and 4. Photos 5 and 6 show an image quality map as well as a secondary electron map. In the image quality map, darker areas represent areas of poor or no signal. These areas correspond to the light areas in the secondary electron map which are areas of catalyst metal created during the HT/HP process. For diamond grain analysis, this loss of signal is not detrimental as it helps to accurately define diamond grain boundaries.

The OIM software can evaluate the incoming crystal lattice data and plot maps of the crystal orientations observed in the sample. Photos 7 and 8 show these color coded maps. In Photo 7 the predicted orientation for the entire scanned area is plotted. In Photo 8, the crystal orientations with a high confidence (greater than 77%) are plotted. As was observed in the image quality map, the dark areas of low confidence are the areas filled with catalyst metal between diamond grains.

## OIM TECHNIQUE PROVIDES A SOLUTION

Previous methods for analyzing PCD grain size vary throughout the industry. One typical method is shown in Photo 9. To achieve some distinction between the diamond grains, voids and metal catalyst, the backscatter detector is used on an SEM to generate a PCD micrograph. Four horizontal lines are drawn on the image, and grain length measurements are made at the intersections of these lines and the diamond grains. Multiple micrographs are obtained per sample, and the grain length data is manipulated in a spreadsheet to get a particle size distribution. This is clearly a tedious task, and not accurate since operator judgment is required to determine what constitutes a grain boundary. Attempts to automate this process with image analysis software have proved ineffective due to contrast problems at voids and grain boundary intersections.

The OIM technique provides an elegant solution to this problem. With the reasonable assumption that similar crystal orientations near each other form a grain, the software can isolate and randomly color each grain. This is shown in Photo 10. Areas of grain boundary ambiguity are eliminated. Since each grain identified by its crystal orientation, size data can be generated. The plot (Figure 2) shows the particle size distribution of the image on the left. Additionally, the software can group similarly sized grains and color them by size. In Photo 11, over 2000 grains were identified and color coded. The color coding is shown in the histogram in Figure 3.

With the extensive crystal orientation data available, grain boundary interactions were also studied. For example, in Photo 12 grain boundaries are highlighted and color coded for their misorientation angle (Figure 4). Yellow indicates low-angle interactions (2°-5°), the mid-range boundaries are shown in red (5°-15°), and highangle boundaries are shown in blue (>15°). The number of low angle grain boundaries is higher than expected for a random sample. What this means for PDC performance is not yet fully understood, but provides great opportunity for research.

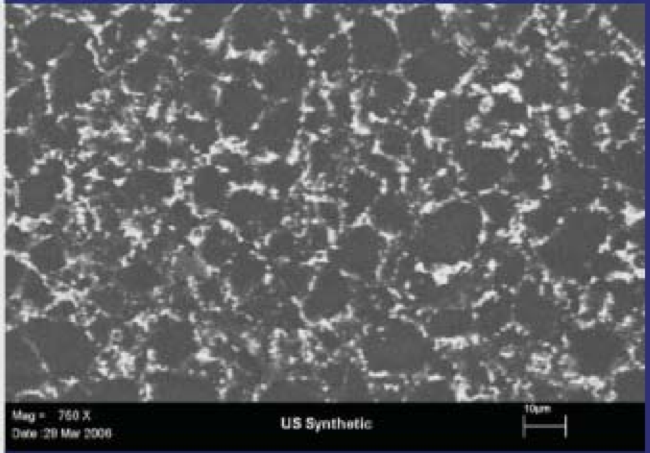


*Photo 2 - Backscatter SEM Image of PCD with a Mirror Finish*

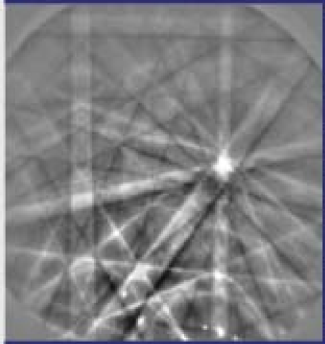


*Photo 3: EBSD Patterns*

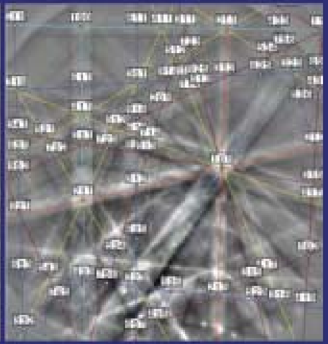


*Photo 4: Orientations Directions*

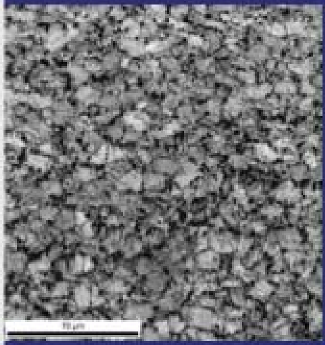


*Photo 5: Image Quality Map*

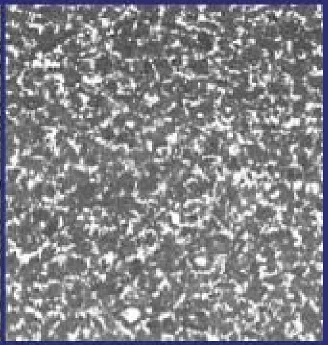


*Photo 6: Secondary Electron Map*

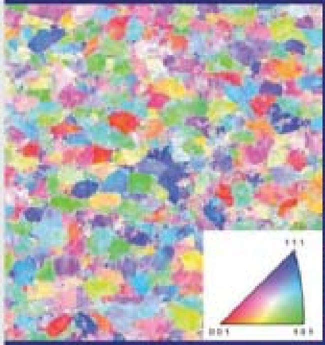


*Photo 7: Crystal Orientation*

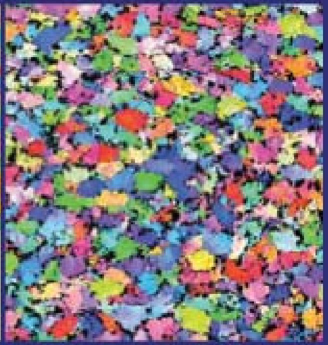


*Photo 8: High Confidence Crystal Orientation*

***Orientation Imaging Microscopy of PCD grain size measurement provides immediate benefits in analyzing durability qualities of PDC and may provide future benefits in designing new and more durable PDC.***

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Which applies to your company: ______ Corporation ______ Partnership ______ Sole Proprietorship
Provide names of principle officers or partners: ______
When was your company established? ______
How long has your company been engaged in superabrasive/ultra-hard material industry? ______

List at least two business references, preferably one is an IDA member (name, company and address of each):
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Any company and/or individual classified as a superabrasive/ultra-hard material supplier, tool maker, machine tool builder, end user or related business with offices in the USA, Canada or Mexico is eligible in this category. Only one individual shall be designated by each member company as the IDA Delegate with voting and other privileges described in the By-Laws.

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Any company and/or individual classified as a superabrasive/ultra-hard material supplier, tool maker, machine tool builder, end user or related business which does not have offices or other facilities in the USA, Canada or Mexico is eligible in this category. An International Member shall have all the privileges of regular membership, except that the delegate cannot vote at any membership meetings, participate in statistical reporting for the North American market, hold proxies or serve in any office in IDA. Annual fee for International Member is **$2,575 per year**.

Name of Delegate Voting Member: ______
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Available for companies having a principal office in the USA, Canada or Mexico, which are providing products or services to the superabrasive/ultra-hard material industry, but are not engaged in selling, using or dealing in industrial diamonds, cubic boron nitride, compacted diamond/cbn, diamond film or products containing diamonds/cbn. An Associate Member shall have all the privileges of regular membership, except that the delegate cannot vote at any membership meetings, participate in statistical reporting for the North American market, hold proxies or serve in any office in IDA. Annual fee for Associate Member is **$500 per year**.

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Each company that enrolls as a Regular or International IDA Member is entitled to have a second person at that company designated an Affiliate Member. The first Affiliate member will receive IDA material at no further cost. Additional persons at Member companies can be added as Affiliate Members to receive IDA materials. Annual fee for Affiliate Member is **$75 per year**.

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Available for any individual who has retired or is no longer active in the diamond or cbn business, but wishes to receive information mailings and attend IDA meetings as a member. Annual fee for Senior Member is **$50 per year**.

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***The Industrial Diamond Association of America, Inc.*** **is a non-profit trade association and was incorporated on March 29, 1946 in the State of New York. It is the oldest and most prestigious association in the superabrasive/ultrahard materials industry. Activity and focus has evolved from natural diamond to superabrasives and most recently, to all ultrahard materials including CVD Diamond. Members include material suppliers, tool manufacturers, component producers, machine tool builders, end users, academia/research affiliates and other companies related to the research, manufacture, application, use and sales of superabrasives.**

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- Interacts With Global Associations And Organizations
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- Organizes And Presents Technical Seminars & Conferences
- Serves As A Government Liaison For Industry Guidelines And Regulations
- Participates As Member Of World Diamond Council
- Provides Safety / Regulatory Reports And Advisement
- Resource For General Information And Consultation

## OTHER MEMBER SERVICES

- PUBLISHES QUARTERLY MAGAZINE
- HOLDS ANNUAL CONVENTIONS
- HOSTS IDA WEBSITE WITH MEMBER FOCUS AND DIRECTION
- PROVIDES SPECIFIC ASSISTANCE ON INDIVIDUAL MEMBER ISSUES
- CREATES AND DISTRIBUTES PUBLICATIONS ON PRODUCTS AND APPLICATIONS
- ACTS AS A COLLECTIVE VOICE FOR INDUSTRY CONCERNS

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*Fax 614-797-2264 or*
*email: tkane-ida@insight.rr.com*

**January 21-25, 2008**
**World of Concrete 2008**
Las Vegas Convention Center
Las Vegas, NV
http://www.worldofconcrete.com

**February 5-9**
**MARMOL 2008**
International Exhibition for
Natural Stone & Machinery
Valencia, Spain
http://marmol.feriavalencia.com

**February 19-22**
**Vitória Stone Fair 2008**
International Marble and Granite Fair
Carapina, Serra, Brazil,
www.fomatur.com.br

**February 19-22**
**TECHNO STONE**
International Exhibition of Natural Stone
International Exhibition Centre
Kiev, Ukraine
www.technostone-ukraine.com

**March 4-6**
**IADC/SPE**
International Drilling Conference
& Exhibition
Caribe Royale, Orlando, Florida, USA
www.spe.org

**March 4-8**
**CSDA**
Annual Convention of the
Concrete Sawing & Drilling
Association Red Rock
Resort & Spa
Las Vegas, USA
www.csda.org

**March 6-9**
**CXISF 2008**
8th China Xiarnen International Stone Fair
Xiarnen International Conference
& Exhibition Centre, Xiarnen, China
www.stonefair.org.cn

**March 11-14**
**REVESTIR**
International Granite, Marble &
Ornamental Stone Exhibition
Transarnerica Expo Centre
Fale Conosco, Sao Paulo, Brazil
www.exporevestir.com.br

**March 11-15**
**CONEXPO**
Trade Show for Construction &
Construction Materials
Las Vegas Convention Center
Las Vegas, Nevada
www.conexpoconagg.com

**March 12-15**
**GRNDTEC 2008**
Grinding Machines Trade Show
Augsburg, Germany
www.grindtec.de

**March 31- April 4**
**METAV**
International Trade Fair for Manufacturing
Dusseldorf Exhibition Center
Dusseldorf, Germany
www.metav.messe-duesseldorf.de

**March 31 - 4**
**April WIRE 2008**
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www.sae.org/congress

***MAY 3-4, 2008***
**Industrial Diamond Association of America**
***Annual Meeting***

The Contemporary Resort
Orlando, Florida USA
www.superabrasives.org

**MAY 5-7, 2008**
**The Contemporary Resort**
**Orlando, Florida USA**
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**September 8-13**
**IMTS 2008**
International Manufacturing
Technology Show
McCormick Place
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www.imts.com

## CALENDAR EVENTS for 2010

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**Nevada USA**
***March 15-17, 2010***
**www.intertechconference.com**

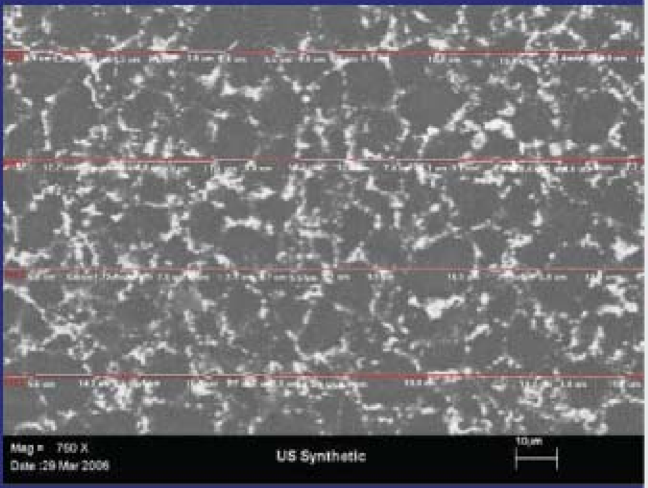


*Photo 9: Manual Grain Size Measurement*

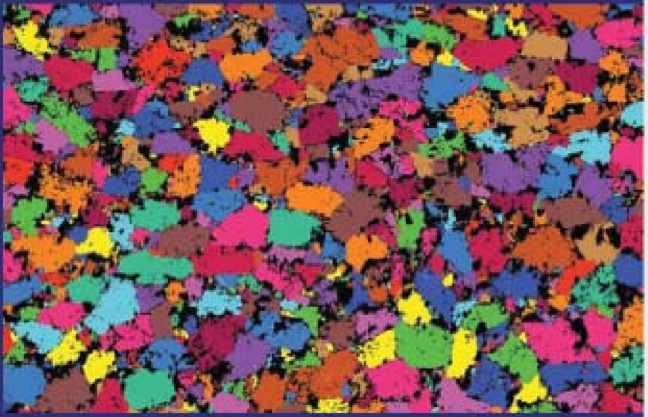


*Photo 10: Individual Grains, Randomly Colored*

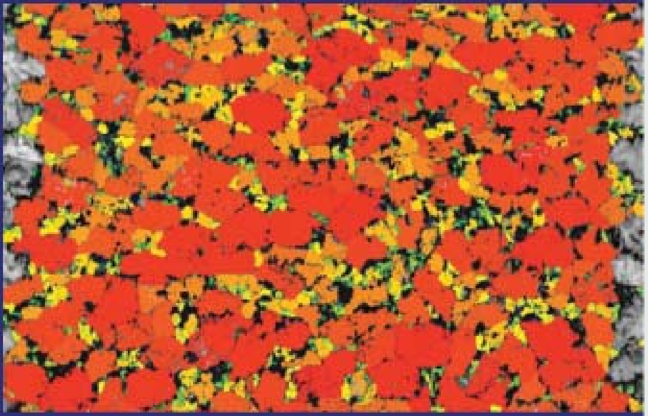


*Photo 11: Grains Coded By Size*

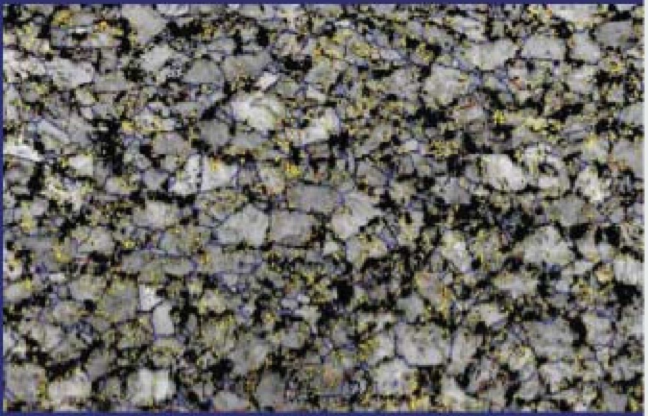


*Photo 12: Grain Boundary Map*

## OIM CAN PLAY A ROLE IN IMPROVING OVERALL PDC PERFORMANCE

With regard to sample preparation, a mirror polish on the diamond table is vital in getting good EBSD patterns. Typical metallurgical polishing is not adequate. The ability of OIM to group similar crystal orientation patterns into grains provides for excellent PCD grain boundary identification. Effectively eliminating the historical problem of SEM image contrast and operator judgment in identifying grain boundaries. Grain size was easily determined and a whole host of other image analysis options are available thanks to the accurately defined grains. The number of low-angle grain boundaries observed in PCD was higher than expected for a random sample. This warrants further study and may play a role in improving overall PDC performance. Future work includes examining crystal orientation found in failure surfaces like wear flats or fractures. This knowledge may not only shed light on root causes of failure, it may lead to intentional orientation of grains in the manufacture of PDC. ■

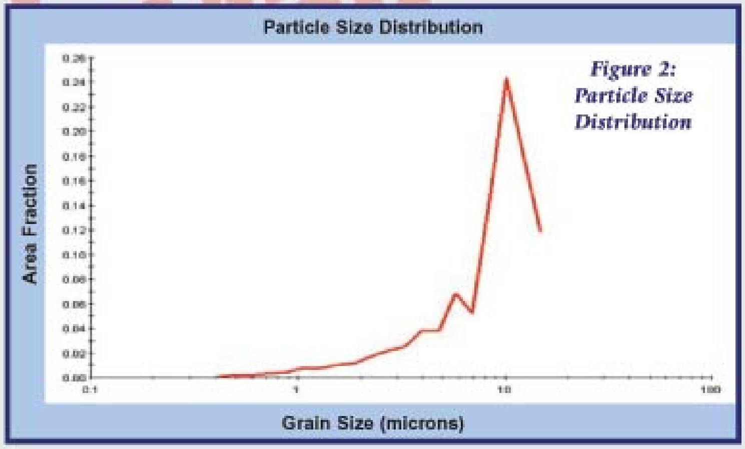


*Figure 2: Particle Size Distribution*

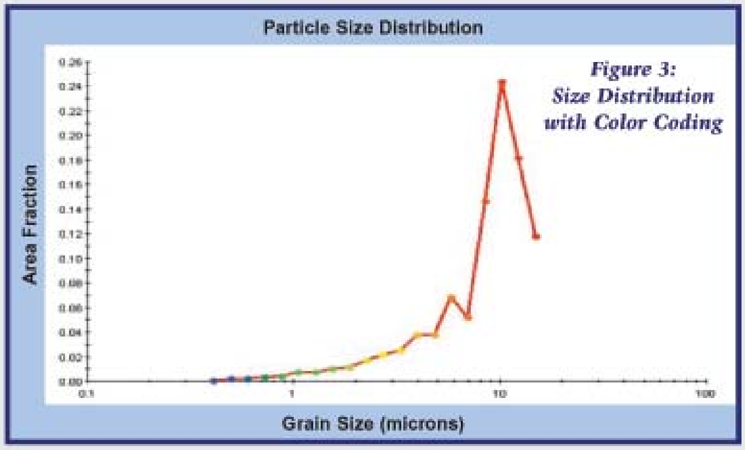


*Figure 3: Size Distribution with Color Coding*

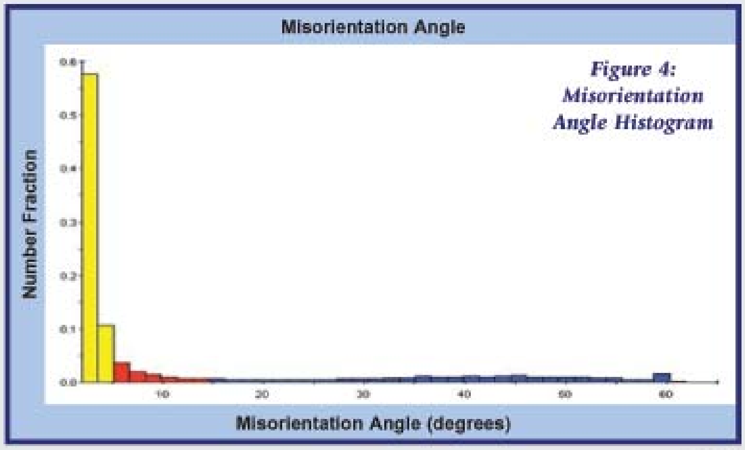
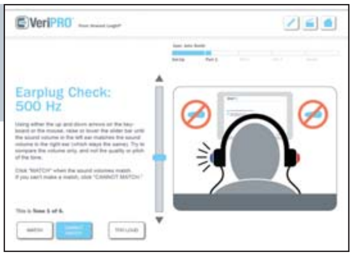


*Figure 4: Misorientation Angle Histogram*

## NEW VERIPRO™ TECHNOLOGY FROM HOWARD LEIGHT MEASURES REAL-WORLD ATTENUATION OF EARPLUGS



***Smithfield, RI*** – New VeriPRO™ technology just introduced by Howard Leight by Sperian now makes it possible for safety managers to ensure employees are getting the most out of their hearing protection devices. Developed in conjunction with the House Ear Institute (www.hei.org), VeriPRO measures real-world attenuation of unmodified earplugs and can be used as a means to improve individual employee training and enhance the overall effectiveness of hearing conservation programs. **For additional information visit www.howardleight.com**

## NEW LATHE & SPINDLE ALIGNMENT TOOL FOR INDUSTRY

***Newburyport, MA,*** December, 2007 – Pinpoint Laser Systems has a new measuring and alignment system for lathes, turning equipment, spindles and related machinery. Easy to use, versatile, and affordable. Ideal applications include aligning lathes and turning centers, adjusting boring mills, aligning drive shafts, adjusting barfeeders, and many other industrial applications. This lathe & spindle alignment system is simple and quick to use with a round laser that is secured into a chuck or attached to the end of a shaft or spindle. New Microgage Spindle Alignment tool can measure to a precision of 0.0001 inch or better and the laser allows for alignments over distances as great as 150 feet. A serial and USB interface connect to a laptop or PC and link to popular spreadsheets for plotting and analyzing data for maintenance records, customer compliance and other uses. **For more information contact Pinpoint Laser Systems, Inc. at 1-800-757-5383, or jkelley@pinlaser.com**

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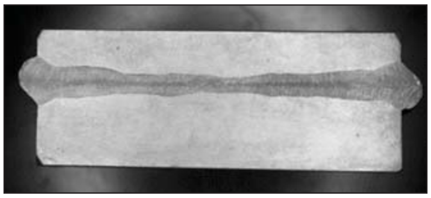
## IPG PHOTONICS ANNOUNCES NEW RESULTS IN THICK PLATE WELDING WITH 20 KILOWATT FIBER LASER

***Oxford, MA,*** December 10, 2007 – IPG Photonics Corporation, the leading global manufacturer of high-power lasers and amplifiers for diverse applications in numerous markets, today announced that its application center in Germany achieved a record high-quality deep penetration welding on thick stainless steel plates at rapid speeds. By using IPG's unique 20 kW continuous wave (CW) 1070 nm commercial fiber laser, it is now possible to weld 1" 304 stainless steel at a speed of 0.85 meters/minute, and 3/4" samples at a speed of 2 meters/minute using a 200 micron fiber cable with a 420 micron focus spot size. In other experiments, IPG also was able to produce high-quality welds on 2" 304 stainless steel samples by applying laser beams from both sides with a total penetration depth of 54-56 mm per pass. IPG's YLR-20,000 fiber laser is the only laser in the world that can produce 20 kW of CW output at 1 micron. **For more information, please visit www.ipgphotonics.com**



*Sample of 2" 304 stainless steel welded with 20 kW IPG fiber laser*

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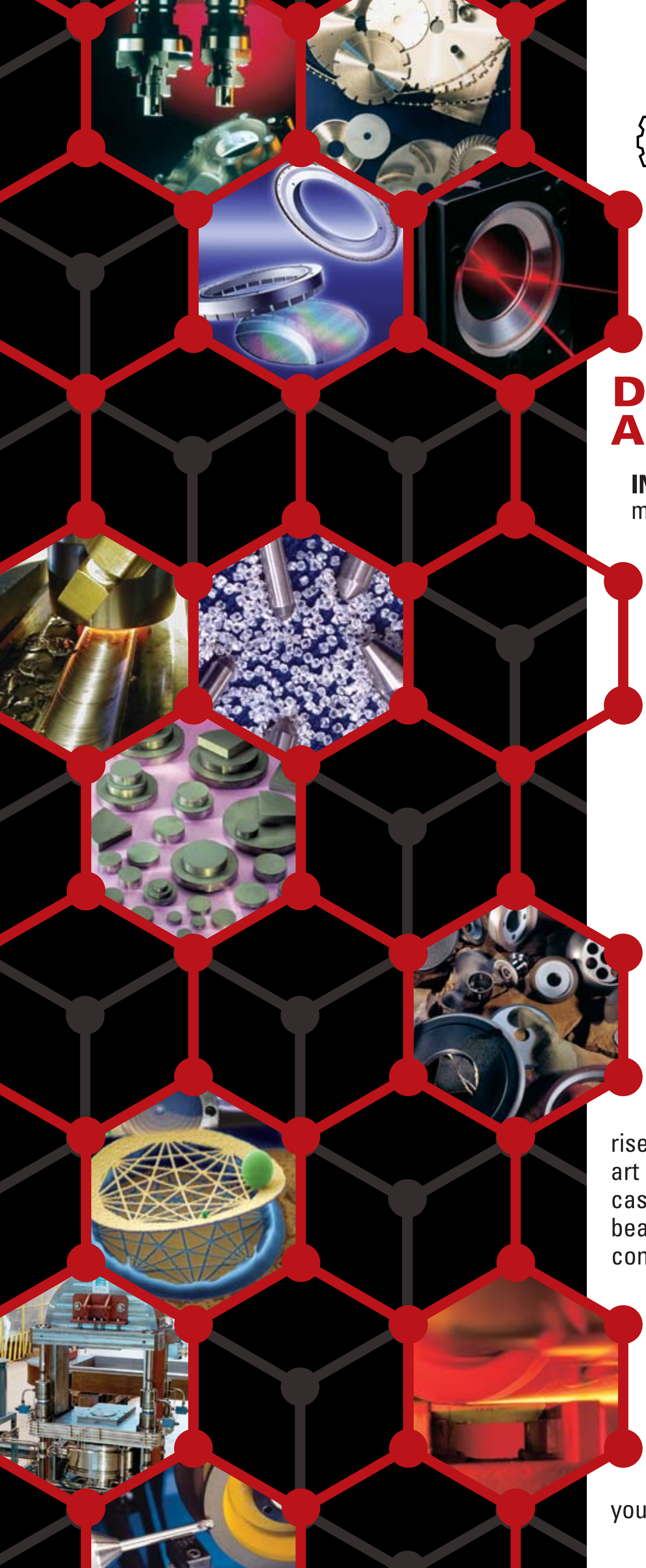

## THE INDUSTRIAL DIAMOND ASSOCIATION OF AMERICA IN COSPONSORSHIP WITH GLOBAL ORGANIZATIONS PRESENTS:

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**INTERTECH 2008** is an International Conference featuring presentations on new and evolving technology for superabrasive materials and how these materials are applied in various industries. **INTERTECH 2008** promises to be the most comprehensive commercial and technical conference ever held on industrial diamond, cubic boron nitride, polycrystallines, CVD diamond and other related superabrasives. **INTERTECH 2008** will feature leading experts representing international Suppliers, Research Facilities, Academia, End-users, Machine Tool Builders and the Scientific Community. They will be presenting papers on subjects that will introduce new technology on superabrasives. This will be an international "meeting of the minds" for every aspect of application and new product development. Whether it's improved crystals and polycrystalline materials or new inroads for natural and CVD Diamond, this conference covers the complete spectrum. From prosthetics or diamond knives in medical to texturing of computer discs, diamond and other "superabrasives" are changing the world in which we live.

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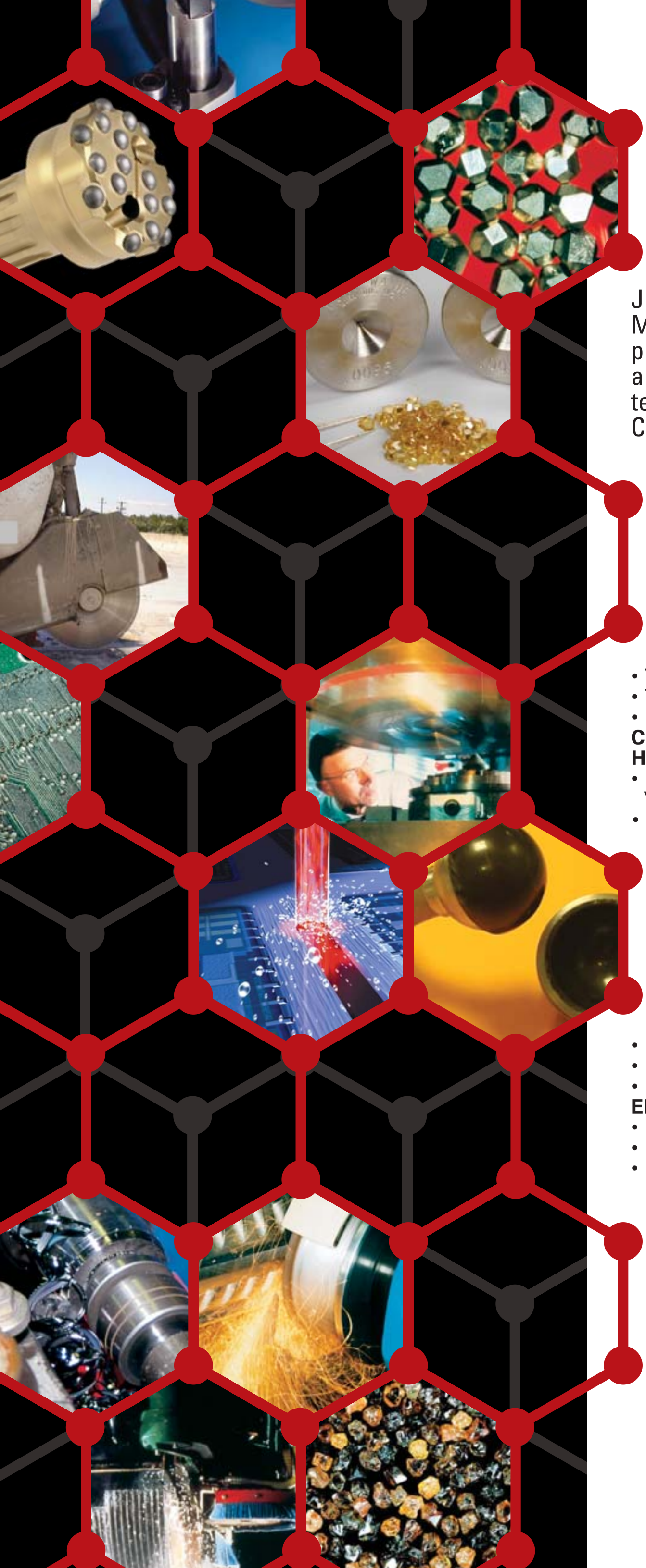
## EXCITING VENUE A MAJOR ATTRACTION FOR INTERTECH 2008

This spectacular event will be held from May 5-7, 2008 at Disney's Contemporary Resort in Orlando, Florida USA. The Contemporary Resort rises majestically above the nearby Magic Kingdom Park. From the dramatic art in the main tower with sleek monorails cruising overhead to the casual style and convenience of Garden Rooms looking out over the beach, this is an experience not to be missed. After a day filled with conference participation, attendees can relax and enjoy the spectacular views of Bay Lake, the Magic Kingdom Park and Seven Seas Lagoon. For dining excitement ahead of its time, experience the award-winning California Grill. Experience the water sport activities from watercraft rentals to water-skiing, parasailing or fishing excursions. All these amenities add to **INTERTECH 2008**, to make it an overall "have to attend" experience. Make this not only a rewarding technical experience, but also an enjoyable trip you will remember for quite a while!



# FINAL CALL FOR PAPERS!

## *DEADLINE JANUARY 31, 2008*

**INTERTECH 2008** will be co-sponsored by the leading global Organizations for this industry - Abrasive Engineering Society, ASM International, Assodiamante, Concrete Sawing & Drilling Association, F.E.P.A., IDA-Americas, IDA-China, IDA-India, IDA-Japan, Japan Society for Abrasive Technology, Society of Manufacturing Engineers (SME) and the Unified Abrasive Manufacturers Association (UAMA). You can be part of this exciting event! We are now soliciting commercial and technical papers of approximately 30 minutes length that address the development of these super-hard materials as well as the dynamics and application of superabrasive systems in all industries and areas (see: Areas of Consideration) with a focus on new technology, tooling, workpiece materials, machines and applications related to increased **PRODUCTIVITY** and **PERFORMANCE**. Consideration for papers is being made at this time and abstracts are now being accepted; contact us today to be considered. This will be the most comprehensive event ever held on superabrasives!

## AREAS OF CONSIDERATION FOR PAPERS

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  - Renovation
  - Block Grinding
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- Wafer Mfg.
- Polishing
- Optic Windows
- Semiconductors
- Heat Sinks

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- New Crystals
- Coatings

**GLASS**
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- Polishing
- Pencil Edging

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- Innovations
- Advancements
- Superabrasive Adaptation

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- Heavy Equipment

**OPTICS**
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- New Coatings
- Bond Development
- Testing/Gauging
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- Materials
- Tooling
- Application Development
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- Magnetorheological Finishing
- Electrolytic In-process Dressing (ELID) Mirror-Surface Grinding
- Nanotechnology

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# PCD Inserts for Improved Hard Rock Mining Efficiency

By: DAN BELNAP, Research and Development Manager Smith Megadiamond – Smith International
LARS HILLBERG, Marketing and Sales Manager Surface Top Hammer & DTH Tools – Sandvik Mining & Construction

Despite the many advancements in PCD materials and component design that have evolved, successful development of a PCD insert for hard rock mining applications has proven to be more difficult. In developing a new product for hard rock mining, it was necessary to take a departure from traditional PCD metallurgy and develop a new material for percussive drilling for hard rock mining. This new material will be reviewed from a microstructure and mechanical properties perspective.

## *Enhanced Insert Design Proven To Be Excellent Solution For Oil And Gas Applications*

Polycrystalline diamond (PCD) enhanced inserts have been successfully employed in oil and gas rock drilling using three cone and percussion bits since the mid 1980's. The basic manufacturing process for PCD is well known and involves subjecting diamond powders to high pressure and high temperature (HP/HT) conditions in the presence of a solvent/catalyst, which creates a sintered material characterized by strong interdiamond bonding. The enhanced insert manufacturing process involves the in-situ bonding of the PCD material to a hemispherical surface on a hard metal (WC-Co) substrate during the HP/HT sintering process. The material properties of PCD include high hardness, wear resistance, and strength, combined with moderate toughness. With these combinations of properties the enhanced insert has proven to be an excellent solution for oil and gas applications. However, despite some limited success, the concurrent development of an enhanced insert product for drilling applications in mining has proven to be more difficult. Oil and gas drilling is somewhat unique in that the intrinsic drilling operation involves placing a drill bit hundreds to thousands of meters deep. The logistics of oil and gas drilling give strong economic advantages to materials such as PCD which provide additional bit life and can the offset substantial increases in drill bit cost by reducing the amount of time required to place tools in and out of the drill hole. In general however, mining applications are more sensitive to cost and therefore the relative performance benefits over conventional drilling tools must be greater than those in the oil and gas industry for the typical mining customer to gain an advantage from PCD over traditional WC-Co insert materials. Some improvements to enhanced inserts have been developed over the past few years that have proven beneficial to performance. One key enabling technology for PCD enhanced inserts was the use of precemented WC-Co composite interlayers with intermediate properties between PCD and WC-Co, which effectively form a functional gradient in the PCD material. The use of precemented WC-Co interlayers has proven to be a good solution to the inherent problem of PCD delamination, however other approaches have since emerged as solutions to enhance insert delamination. For 3-cone bit applications, changes in enhanced insert design combined with cutting structure optimization have also been developed with reported positive effects on performance. From the perspective of PCD materials development, structured PCD/WC-Co composite materials research provided a significant new direction for enhanced insert materials. Additional work on composite PCD materials shows that both structured and unstructured/homogeneous composite materials give performance benefits in three cone bits. This research clearly shows that an inverse relationship between hardness and impact resistance could be exploited to improve overall enhanced insert performance. This product was the result of changes to insert design, and PCD material for hard rock mining. With these changes a durable and cost-efficient PCD insert product has emerged, which has shown significant operational cost savings and efficiency for the mining operation compared to WC-Co inserts.

## *Bit Design Considerations*

The bit design employed 18 mm diameter PCD enhanced inserts on the gage row. Traditionally the 18mm diameter insert has employed a 10.0 mm radius defining the PCD dome surface, however previous experience with premature PCD breakage in similar mining applications led to testing an elliptical dome shaped insert with an effective radius of 13.0 mm defining the contact region. Representative figures showing the dome shapes are shown in Figure 1.

Calculations were performed using the elastic constant values in Table 1, with the values for PCD elastic modulus and Poisson's ratio was 0.20. Since it is so commonly encountered in hard formation drilling and it a well-characterized mineral, quartz was assumed to be representative of the elastic response of the formation material. The results of these calculations are shown in Figure 2.

In comparison to the actual situation, the complex failure response of the rock formation and the effects of impact vs. static loading are simplified in these calculations. However, the effects of the increased radii on in reducing the PCD contact stresses are clearly shown. Analysis of the calculated stresses in Figure 2 shows that the 13.0 mm dome radius reduces the tensile stress by 15.7% over the 10.0 mm dome radius. Another design feature of the enhanced insert was functional gradient layering between the PCD material and the WC-Co substrate. This "transition layer" technology incorporated two layers with blends of PCD and WC-Co in respective amounts of PCD 60 vol%/WC-Co 40 vol% and PCD 40 vol%/WC-Co 60 vol%. These materials form interlayers of intermediate elastic and thermal expansion properties between the PCD material and the WC-Co substrate which aid in preventing delamination of the PCD material. In addition, the PCD layer incorporated an optimized layer profile design in which the maximum PCD layer thickness was not at the apex of the dome apex but rather was at an off-axis location corresponding to the idealized contact point of a gage insert with the formation wall during the drilling process. Previous work had shown that using this design approach in percussive drilling showed benefits in enhancing the drilling life enhanced inserts by preventing premature cracking of the PCD layer. A schematic view of a sectioned enhanced insert design used is shown in Figure 3.

## *Test Materials For Potential Use In Mining Applications*

Two candidate materials were tested for potential use in this mining application. The first (PCD-A1) is a material traditionally used in oil and gas applications consisting of a 5 micron grain size diamond blended with 20 wt% (9 vol%) cobalt. The second material (PCD-A2) was an experimental grade consisted of 5 micron diamond blended with 30 wt% (14 vol%) cobalt. Secondary electron SEM microstructures of these materials are shown in figures 4a and 4b. Clear differences in metal content and diamond grain contiguity can be observed in these micrographs.

Material characterization of these materials was performed to better understand the property differences between these grades using procedures described elsewhere. Hardness measurements were predictable based on differences in the composition and microstructure. Flexural strength measurements showed that the PCD-A2 material had a mean strength about 6% higher than PCD-A1, however some increase in standard deviation was observed. A significant increase in impact resistance was seen with PCD-A2 material, which was expected based on the decreased hardness and previous observations. Also the wear resistance of the PCD-A2 material had a measurable drop, which was also expected based on the lower hardness of this material.

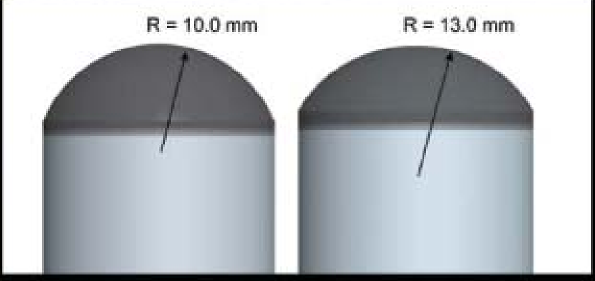


*Figure 1: Insert Dome Profiles and Effective Radii*

To estimate the effect of contact stress reduction with changing dome radii, calculations were made using standard Hertzian contact equations. For these calculations, the average contact stress $\sigma_c$ is give by:

$$\sigma_c = \frac{P}{\pi a^2}$$

were P is the applied load and *a* is the radius defined by the contact of a sphere of radius R. The Hertzian equation for the contact radius *a* is given by:

$$a = \left[\frac{4kPR}{3E_1}\right]^{1/3}$$

where k is given by the relation

$$k = \frac{9}{16}\left[(1 - v_1^2) + (1 - v_2^2)\,\frac{E_1}{E_2}\right]$$

where $E_1$ and $v_1$ are the elastic modulus and Poisson's ratio of PCD and $E_2$ and $v_2$ are the elastic modulus and Poisson's ratio of the information. The tensile stress is given by the relation

$$\sigma_T = \frac{(1 - 2v_1)}{2}\,\sigma_c$$

| $E_1$ (PCD) | $v_1$ (PCD) | $E_2$ (Quartz) | $v_2$ (Quartz) |
|---|---|---|---|
| 890 GPa | 0.20 | 72 GPa | 0.17 |

*Table 1. Elastic Properties of PCD and Quartz*

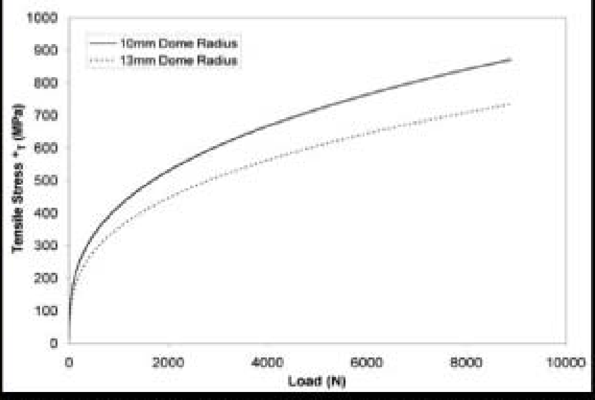


*Figure 2: Tensile Stress vs. Applied Load Differing Dome Radii*

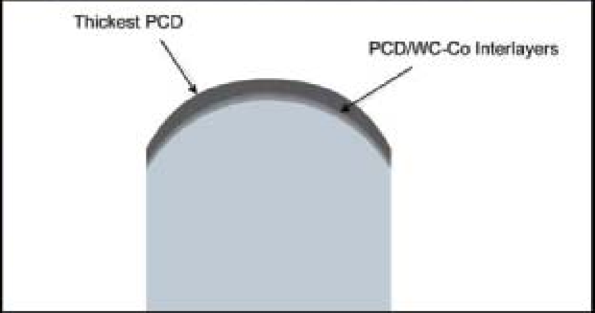
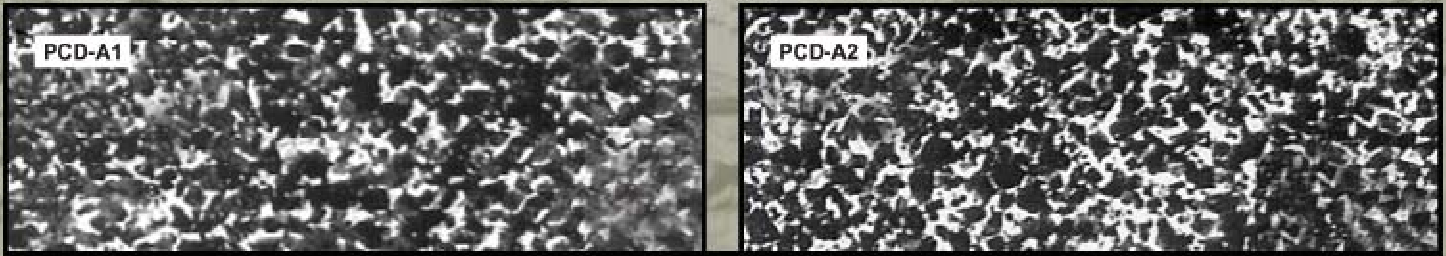


*Figure 3: Schematic View of Enhanced Insert*



*Figures 4a & 4b: PCD-A1 and PCD-A2 Microstructures*

## Percussion Bit Test Results

The enhanced inserts were used in gage locations on a percussion bit, while standard tungsten carbide/cobalt inserts were used in the face locations. The gage locations are the most demanding, as these inserts are required to maintain the hole diameter in addition to comminuting the formation during the drilling process. The percussion bit used in these tests is shown in Figure 5.

Three types of PCD gage inserts were tested: 1) PCD-A1, PCD thickness T = 0.35 mm, 2) PCD-A2, PCD thickness T = 0.70 mm, and 3) PCD-A2, PCD thickness T = 1.05 mm. All PCD inserts tested used the blunter dome geometry mentioned earlier. The PCD insert performance was compared against a baseline of WC-Co gage inserts. For versions 2 and 3 above, additional PCD thickness was employed because the relative wear resistance of the PCD-A2 material was significantly lower than the PCD-A1 material used in version 1; therefore, it was necessary to compensate for this difference with additional material. The relative performance of bits using the various PCD gage inserts normalized to the WC-Co baseline is shown in Figure 6.

All of the PCD gage inserts showed an increase in performance relative to WC-Co inserts. The use of PCD-A2 material in combination with a 1.05 mm thickness gave the most improvement. The PCD-A1 material with the 0.35 mm PCD layer gave the least relative improvement, with the PCD-A2 material with 0.70 mm thickness giving intermediate test results.

## Enhanced Performance Of Percussion Bit For Hard Rock Mining

An important factor to keep in mind when comparing the performance of PCD enhanced to WC-Co bits used as a baseline comparison is that the carbide bits achieve this lifetime only through extensive regrinding /resharpening operations. A WC-Co bit will be resharpened 3-4 times during typical use in hard rock mining due to the significant dome blunting occurring by excessive abrasive wear in

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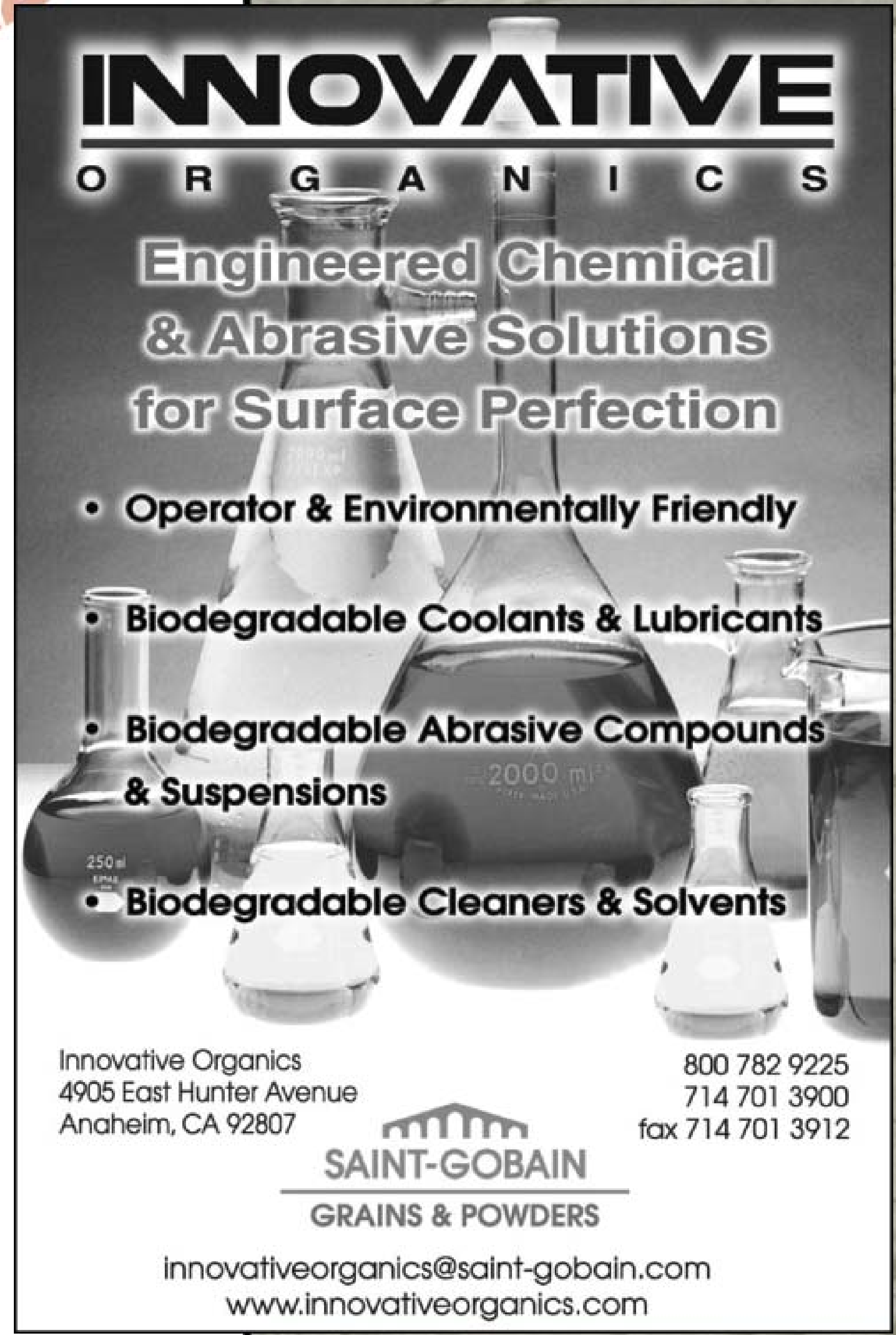
which the dome becomes essentially a flat surface. However, the testing with PCD enhanced bits showed that a moderate amount of wear of the PCD clearly has some performance benefits. The use of PCD-A2 material in combination with a 1.05 mm PCD layer and design modifications including a blunter dome surface and an optimized layer configuration was clearly able to generate the best test results. The relative improvement of the 1.05 mm PCD-A2 thickness insert over the 0.70 mm PCD-A2 thickness is a clear demonstration that a steady-state wear condition was achieved during the drilling. This was a critical development as it demonstrated that additional service life could be achieved simply by addition PCD layer thickness. The wear profile of the PCD-A2 material is shown in Figure 7. In contrast, the PCD-A1 material failed by chipping/spalling at a comparatively early stage during the drilling. The addition of layer thickness to the PCD-A1 material is unlikely to give additional performance benefits, as the material is inherently too brittle for the application.

The "engineered wear" of the PCD-A2 material is believed to be due to the ability of this material to remove contact induced surface cracking before the cracks reach the critical size necessary for catastrophic crack propagation. This is achieved by having a PCD hardness that is optimized for a balance between wear extremes, these being the wear resistance of WC-Co that has excessive wear and traditional PCD that has insufficient wear. The range of PCD hardness values between 2000-3000 kg/mm2 appears to have many advantages for enhanced inserts. Also considered important to achieving this performance is the modified dome shape and layer configuration in the insert design. The flexural strength and impact resistant properties of PCD-A2 previously discussed also give this material important mechanical advantages over the PCD-A1 material that likely assist in preventing crack initiation independent of the wear mechanism. It is likely that the same types of competing mechanisms between surface cracking and wear are active in WC-Co materials, as the successful matching of WC-Co grade with application is almost always a balance between grades with high wear resistance/low toughness which tend to fail prematurely by fracture and grades with low wear resistance/high toughness which tend to fail prematurely by high rates of wear. Subsequent testing confirmed the initial results and has led to the development of a new commercial PCD percussion bit product for hard rock mining. The sustained drilling performance of these bits has made it possible to improve a mining operation in several different ways including productivity, total drilling operational cost, fragmentation and automation. As an example, the sublevel

| Material | Hardness | Flexural Strength | Impact Resistance | Wear Resistance |
|---|---|---|---|---|
| PCD-A1 | 3300-3400 kg/mm2 | 1719 ± 97 MPa | 50.2 Joule | 1.03 x $10^6$ |
| PCD-A2 | 2650-2750 kg/mm2 | 1827 ± 234 MPa | 69.2 Joule | 0.39 x $10^6$ |

*Table 2: Material & Functional Properties of PCD-A1 & A2 Materials*

***Successful development of a PCD insert for hard rock mining applications has proven to be difficult.***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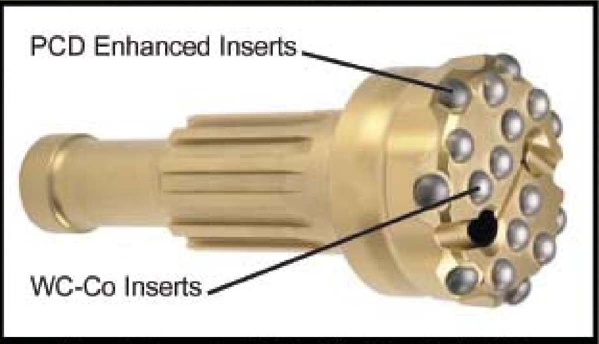

*Figure 5: Percussion Bit Used for Hard Rock Mining*

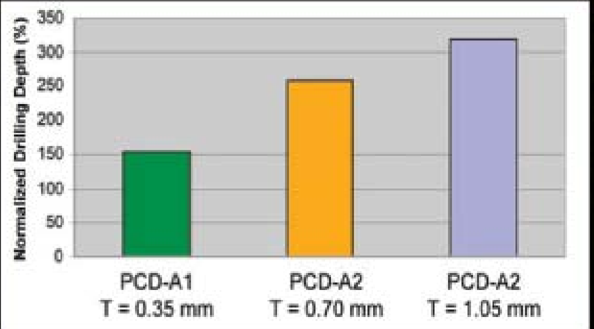

*Figure 6: Percentage Drilling Depth Relative to WC-Co Gage Bits*

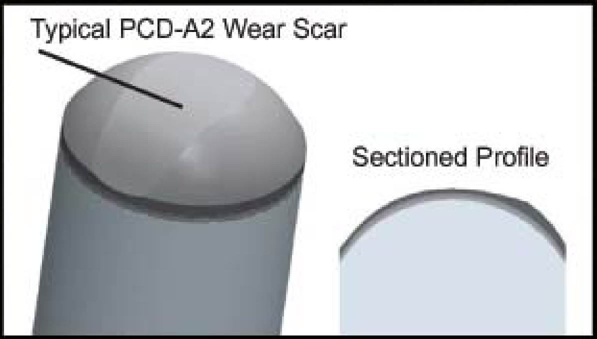

*Figure 7: Wear of PCD-A2 Gage Inserts*

## Performance Improvement In Hard Rock Mining

PCD-enhanced inserts using modifications to standard PCD insert geometry, layer design, and material composition have shown technical and commercial success in hard rock percussive mining. PCD material with lower hardness and wear resistance (which allows for a controlled amount of wear in the application) shows performance improvement in hard rock mining relative to PCD material with a higher hardness and wear resistance.

stoping mining method requires holes to be drilled in a fan pattern to depths of 50-60 meters and in many cases in ore that is hard and abrasive. PCD enhanced bits have been observed to make substantial improvements compared to standard WC-Co bits in this application. The main advantages observed with PCD-enhanced bits are: 1.) Even the deepest hole can be drilled in one pass, eliminating tripping out of the hole to change a worn bit 2.) Higher average penetration rate in drilling due to the fact that the inserts retain a dome shape for longer period of time 3.) Reduced service and maintenance requirements, which leads directly to fewer bits in circulation, fewer inserts to regrind, and longer intervals between regrinding 4.) More constant bit diameter, which makes it possible to reduce the hole diameter compared to using standard bits and enables a more consistent distribution of explosives in the blast. Theoretically this can improve rock fragmentation, and presents an opportunity to increase hole spacing that can further reduce costs. The actual productivity improvements and cost reductions will vary from mine to mine, depending on a number of parameters such as rock conditions, hole depths, utilization of drill rigs, and production requirements. A major mining operation has now been using PCD enhanced bits for about two years, and as a result they have experienced significant improvements in productivity while simultaneously lowering the total drilling cost. The results are presented below.

| **Productivity** | **Standard Bit** (%) | **Diamond Bit** (%) |
|---|---|---|
| Drill meters/shift | 100 | 139 |
| Drill meters/year | 100 | 139 |
| **Cost Groups** | | |
| Labor cost/meter | 100 | 72 |
| Rig cost/meter | 100 | 74 |
| Variable cost/meter | 100 | 94 |
| **Bit Cost/Meter** | | |
| Total Drilling Cost | 100 | 97 |
| Total cost/year (all rigs) | 100 | 119 |
| Total cost/meter | 100 | 86 |

Most of the productivity improvement above stems from the ability of the PCD enhanced bits to drill even the deepest holes without changing bits. Previously, a 60 meter hole required up to three standard WC-Co bits requiring significant increases in operational down time, bit inventory, and resharpening logistical complexity. This customer was able to utilize the productivity improvement to reduce the number of rigs in operation. It also became possible for this mine operation to automate the drilling process, allowing unmanned operation of drill rigs without decreases in productivity. After reducing the number of rigs with 25% the below results were reported.

| **Productivity** | **Standard Bit** (%) | **Diamond Bit** (%) |
|---|---|---|
| Drill meters/shift | 100 | 104 |
| Drill meters/year | 100 | 104 |
| **Cost Groups** | | |
| Labor cost/meter | 100 | 72 |
| Rig cost/meter | 100 | 74 |
| Variable cost/meter | 100 | 94 |
| **Bit Cost/Meter** | | |
| Total Drilling Cost | 100 | 97 |
| Total cost/year (all rigs) | 100 | 89 |
| Total cost/meter | 100 | 86 |

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# Development Of New PDC Material And Evaluation Of Properties

By: BYONG JOON PARK, JEANG OOK OH
ILJIN Diamond Co., Ltd

KYU SEOK KIM, KYU HWAN OH
School of Materials Science and Engineering,
Seoul National University

***Increased oil consumption has led to the exploration of oil field in much deeper and severe conditions than before. More and more PDC drill bits are used in oil well drilling to reduce total drilling cost and it is expected that the number of PDC drill bits exceeds that of conventional "tri-cone" bits in a near future. A new PDC drill bit has been developed and its properties tested. Computer-aided simulation was performed to analyze the residual stress between the diamond layer and the substrate; results were utilized to design a new interface. Optimal composition of multi-modal diamond grains was chosen to maximize the direct bonding of diamonds. Microstructure analysis and granite turning, shock and wear tests were performed on the new PDC along with others available in the market.***

## PDC Cutters Have Helped Change The Oil And Gas Exploration Bit Industry

Sintered diamond materials are widely used today as the cutting elements in metal-cutting tools, drilling bits and wear parts for wire-drawing dies. Among these applications, polycrystalline diamond compacts (PDC) are extensively used as drag bit cutters on bits used to drill oil and gas wells. After their introduction in the middle 1970's and their initial growth, PDC cutters have helped change the oil and gas exploration bit industry. PDC bits are now over 50% of the bit market and are still growing. Diamond elements for use in the bit industry have been one of the fastest growing segments of the super-abrasive industry. Commercially available polycrystalline diamond compacts are usually made by sintering diamond powders in the temperature range 1500°C to 2000°C at pressures of 5 to 7 GPa by using suitable metallic solvent/catalysts. The individual diamond crystals bond to each other and to the cemented tungsten carbide (WC) substrate under these extreme pressure and temperature conditions. As pressure is released and the PDC is allowed to cool, the diamond layer and substrate material respond at different rates, giving rise to residual stresses in the PDC. This is because of the mismatch of thermal expansion coefficients between diamond and the catalyst metals. The mismatch of thermal expansion coefficients may induce significant internal stress and may generate micro-cracks within the polycrystalline diamond layer. In a more macroscopic sense, the differential thermal expansion of the polycrystalline diamond layer and the tungsten carbide substrate may also result in significant residual stresses in the PDC cutter upon cooling after the sintering process. These residual stresses may also be important in determining the susceptibility of PDC cutters to fracture and to the modes of fracture of these cutters. It is necessary to understand the residual stress in PDC to improve the performance. To reduce the residual stress of PDC, non-planar interface between PCD layer and WC substrate is used. Using computer-aided simulation in order to analyze the residual stress between diamond layer and the substrate, optimized interface is designed. In this work, the residual stress in PDC is calculated using ABAQUS program. According to this calculation a design was used to make a non-planar type of PDC that minimizes the residual stress. Also, measurement was taken of the PDC abrasion/impact resistance.

| Properties | WC-Co | PDC |
|---|---|---|
| Elastic Modulus (GPa) | 545 | 854 |
| Thermal Expansion Coefficient (x10-6/K) | 6 | 2.36 |
| Poisson's Ratio | 0.22 | 0.22 |

*Table 1: Material Properties Used in the Computation*

## Experimental Procedures To Test New PDC Material

### *Analysis of residual properties*

Residual stress analysis was computed in Seoul National University using a commercially available finite difference code (ABAQUS). Table 1 shows material properties using analysis. To decide interface design that optimized the residual stress of PDC, various designs were calculated. According to these results, the best design of substrate was developed.

### *Mechanical properties of new PDC*

After calculation of the residual stress of the PDC having non-planar type interface, the PDC was sintered using a belt type press under HPHT (high pressure and high temperature) conditions. The newly developed PDC has several sizes of diamond; the main diamond size is about 30µm, which is similar to that of coarse grade PCD. This grain size shows good wear performance in a series of PCD types. A multi-modal diamond composition was chosen to maximize the direct bonding of diamonds in order to improve the wear performance of the PDC.

Abrasion and impact resistance of the PDC was evaluated and a granite turning test and wear test for evaluating the abrasion performance of the PDC was completed. The granite turning test method and test conditions are shown in Photo 1 and Table 2. For the wear test, synthetic diamond (ISD-1600 50/60) was chosen and the PDC was worn away on the synthetic diamond. Measuring the weight change, the wear resistance of the PDC can be evaluated by the equation: Wear Resistance = 14 / (Weight change + 0.14)

At Figure 1 and Table 3, wear test machine and test conditions are shown. For the impact test, a hardened steel plate hits the PDC. Weight change, length and width of the damaged zone were measured after test. By these values, impact resistance was calculated by equation:

$$\text{Impact Resistance} = 0.5 \times \left( \frac{10 \times (10\text{- (damage length} \times \text{damage width))}}{2 \times \text{PCD thickness}} + \frac{4}{(\text{weight change} + 0.04)} \right)$$

At Photo 2 and Table 4, impact test machine and test conditions are shown. All tests were performed in with the newly developed PDC and several other commercial PDC types to compare the mechanical properties.

## New PCD Test Results

### *Residual stress analysis of PCD*

The residual stresses of planar-type PDC materials having various thicknesses of PCD layers was calculated. Figure 2 shows maximum principal stresses of planar-type PDC material. In this study, the thickness of the substrate is fixed at 7.6mm. Increasing the PCD layer thickness from 0.5 mm to 3.0mm, the maximum residual stress increases from 145 MPa to 217 MPa. Also, the point that indicates maximum stress moves to the center of the PDC. This trend of stresses is similar with previous studies. This residual stress occurred during the sintering process and is the main cause of failure for PDC material. So it is necessary to reduce the residual stress of PDC. To reduce the residual stress, a capped-hoop at the interface was inserted. Figure 3 and 4 show the maximum principal stresses of PDC material having a capped-hoop inserted interface with various thickness and shapes of capped-hoop. As shown at Figure 3 the residual stress increases as the capped-hoop's height is changed from 1.5mm to –1.0mm. PDC with minimum residual stress can be obtained when the height of capped-hoop is in the range of 0.5~1.0mm, 10~15% reduction of the residual stress compared with planar type interface. When height of the capped-hoop is fixed at 1.0mm, the residual stress of PDC increases with decreasing capped-hoop's diameter. But if the diameter is smaller than critical diameter (in this study, about 75% of total diameter), the residual stress decreases. The residual stress can reduced more when making slope at outside of the capped-hoop. Figure 5 shows changes of the residual stresses with the angle of slope. As decreases the angle of slope, decreases the residual stress. According to the calculations, the residual stress will be minimized at -30° angle slope. By inserting pin on top of the capped-hoop, the residual stress can be slightly reduced. Figure 6 shows the residual stress changes with the depth of the pin. The residual stress decreases by increasing the depth of the pin, but pins with

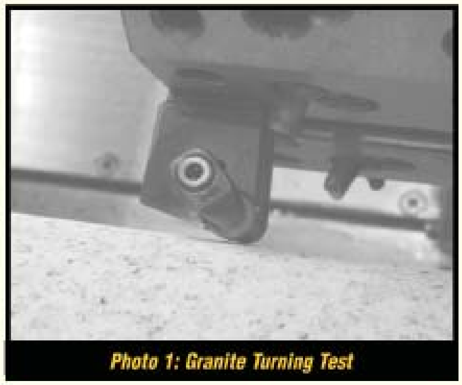

Photo 1: Granite Turning Test

| Work Place | Granite |
|---|---|
| Speed (V) | 450 m/min |
| DOC | 0.25 mm |
| Feed | 0.20 mm/rev |
| Coolant | Wet |

Table 2: Test Conditions of Granite Turning Test

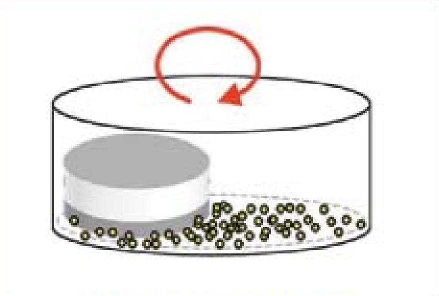

Figure 1: Wear Test Machine

| Work Place | ISD-1600 56/60 |
|---|---|
| Mass of Diamond | 6 cts |
| Speed | 150 rpm |
| Time | 4 hrs |

Table 3: Test Conditions of Wear Test

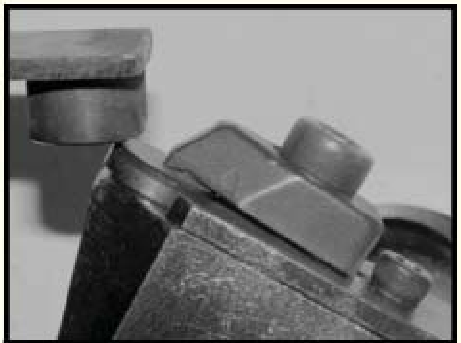

Photo 2: Impact Test Machine

| Work Place | Hardened Steel |
|---|---|
| Speed | 60 rpm |
| Time | 5 sec |

Table 4: Test Conditions of Impact Test

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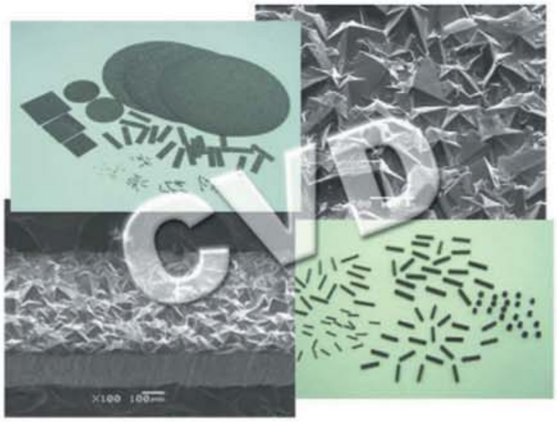

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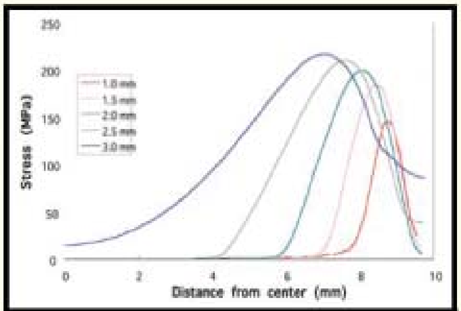


Figure 2: Maximum Principal Stresses with Various PCD Layer Thickness

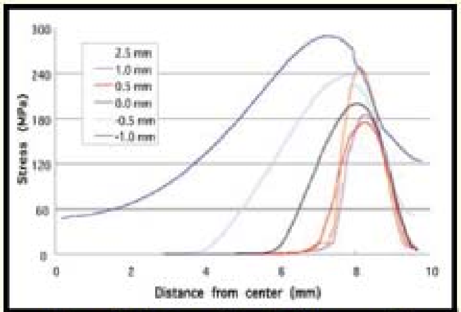


Figure 3: Maximum Principal Stresses with Different Height of Capped-Hoop

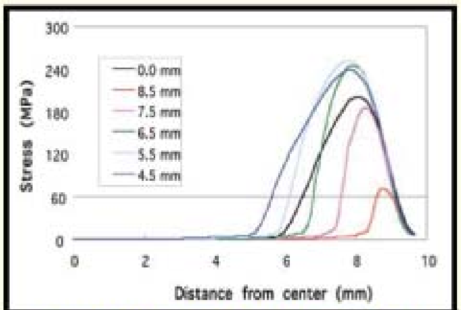


Figure 4: Maximum Principal Stresses with Different Diameter of Capped-Hoop

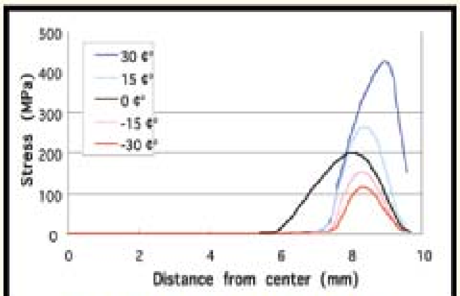


Figure 5: Residual Stress Change with Different Slope Angle

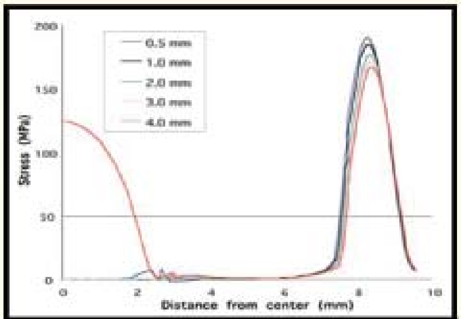
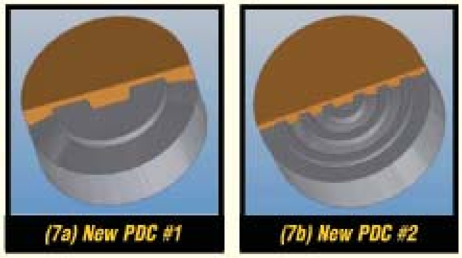


Figure 6: Residual Stress Changes with Depth of the Pin

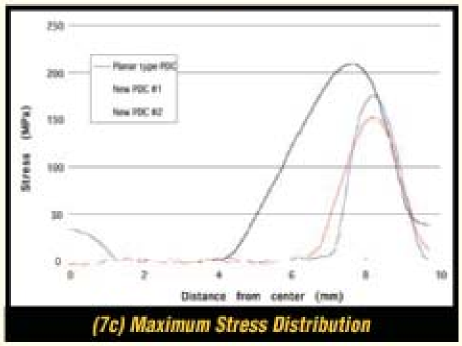
more than 2mm depth caused stress concentration at the center of the PDC. This stress concentration is harmful to the PDC material when used in a drilling operation. According to these results, a new design for the interface was made and calculations were completed for the residual stress of the newly developed PDC. The newly developed interface and its residual stress are shown in Figure 7. To minimize the residual stress, there is capped-hoop on the interface. A pin is inserted in the capped-hoop and a slope is made at the outside of the capped-hoop. By this interface, the residual stress of the newly developed PDC can be reduced up to 30% compared with a planar type PDC with 2.5mm PCD layer thickness.

Figure 7: Newly Developed Interface and Residual Stress of PDC and Their Stress States



(7a) New PDC #1

(7b) New PDC #2



(7c) Maximum Stress Distribution

## Microstructure Analysis

According to these calculations new PDC material having main diamond grain size about 30μm was made. The binders are Co and WC and some binders are premixed and some are infiltrated from substrate on HPHT sintering. Total thickness of the PDC material is 8 mm and the PCD layer thickness is about 2 mm. To maximize the direct bonding of diamond, multi sized diamond powder mixture was used and the binder phases were restrained. The results of microstructure analysis are shown in Figure 8. New PDC #1 and #2 have similar compositions; 15 weight percents of Co and 3 weight percents of WC.

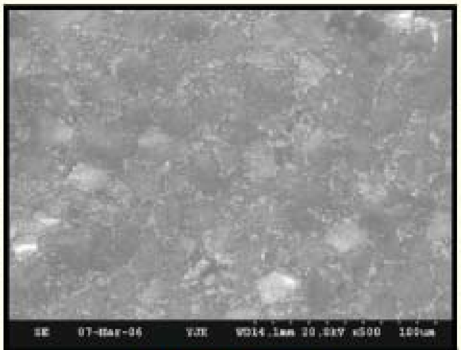
## Evaluation of mechanical properties by lab test

Evaluation was made for the wear and impact properties of the newly developed PDC material. For comparison of the mechanical properties of the new PDC, testing was accomplished on the newly developed, coarse grade PCD and other commercial PDC materials. With the granite turning test results shown in Figure 9, the newly developed PDC showed good wear performance. While cutting the granite at about 5 Km, the new PDC material showed 350μm of flank wear and the other PDC materials were at 600μm of flank wear when cutting only about 1.5 Km. In the granite turning test the newly developed PDC showed several times better performance compared to conventional PCD and other materials. Wear resistance of the PDC materials is shown in Figure 10. Similarly, with granite turning test results, the newly developed PDC indicated higher wear resistance than others. Compared with other PDC material types and conventional coarse grade PCD, the new PDC materials showed about 20% improved wear resistance. Impact resistance of the PDC types is shown in Figure 11. The impact resistance of new PDC is about 45. That of other PDC types is around 38 and conventional PCD indicates an impact resistance of 24. Compared with other products, the impact resistance of the newly developed PDC showed a 50% improvement

## New PDC Material Expected To Give Maximum Performance And Overall Less Drilling Costs

By using computer-aided simulation on the residual stress that occurs during the sintering process, a clear understanding can be formulated for the factors affecting the residual stress of PDC. To reduce the residual stress of PDC, a capped-hoop and slope around hoop was made. By using the calculations of the residual stresses on various interfaces, new interfaces can be designed that reduce the residual stress up to 30% compared with planar type PDC with a

2.5mm PCD layer thickness. Using multi-sized diamond powder mixtures, new PDC material was made having maximized the direct bonding of diamond powers using Co and WC binders. Evaluation of the mechanical properties for the newly developed PDC material was accomplished with the granite turning test, wear test and impact tests. On the granite turning test and wear test, the newly developed PDC showed 3 times better wear performance compared with conventional PCD and other PDC types. And impact test results show that the new PDC has good impact resistance, with up to a 50% improvement. These improved test results are caused by the reduction of the residual stress of the PDC and maximization of the direct bonding of diamond. Reduction of the residual stresses of the PDC was affected to strengthen the bonding of PCD layer and substrate. Thus, PDC material having less residual stress is expected to give maximum performance and overall less drilling costs. ■



*(a) Miscrostructure*

*(b) Peaks of EDS*

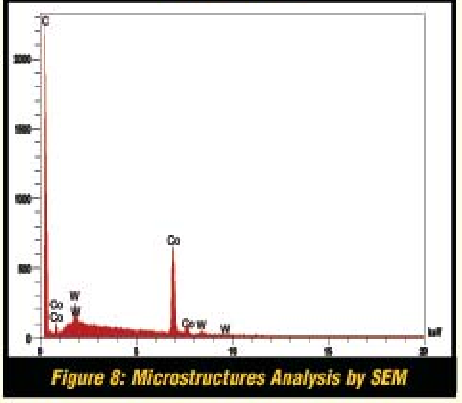


*Figure 8: Microstructures Analysis by SEM*

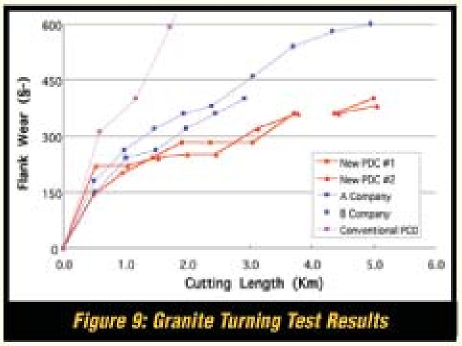


*Figure 9: Granite Turning Test Results*

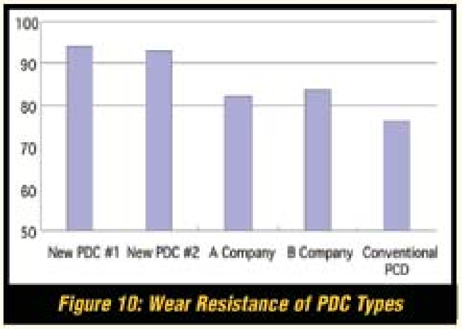


*Figure 10: Wear Resistance of PDC Types*

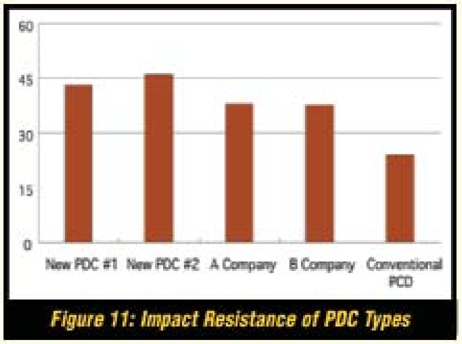
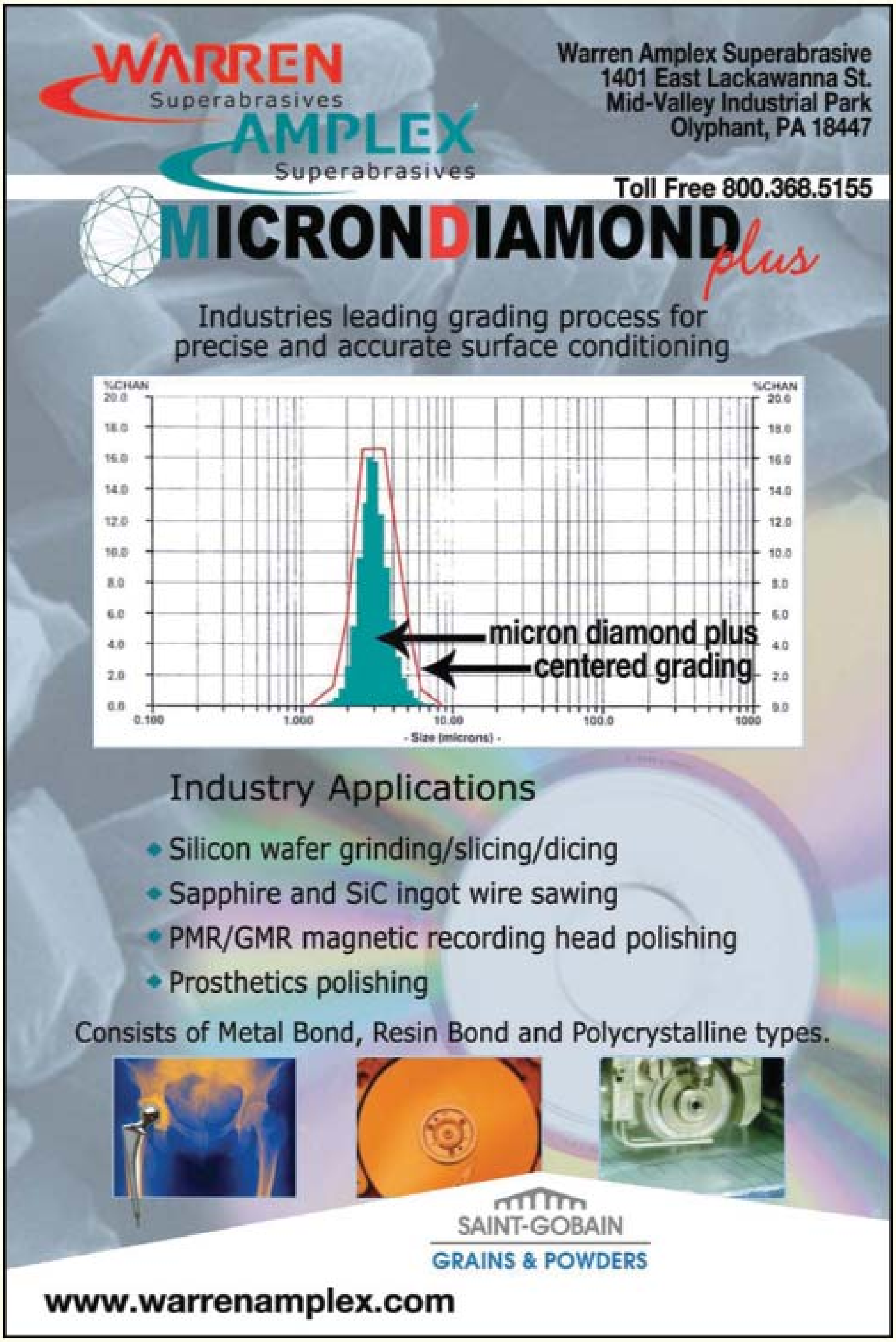


*Figure 11: Impact Resistance of PDC Types*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|---|---|---|
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| Summer 2008 | INTERTECH Highlights | May 31, 2008 |
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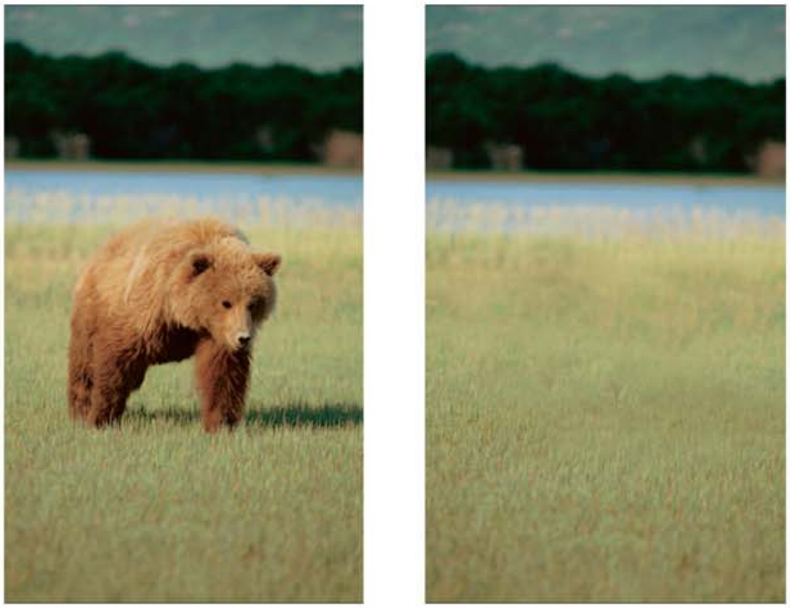

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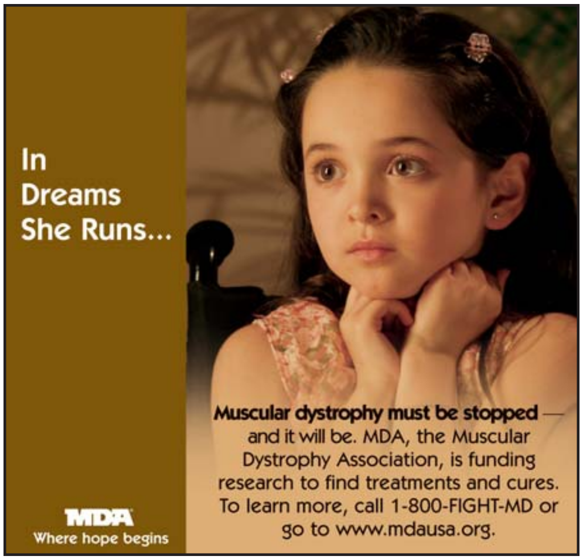

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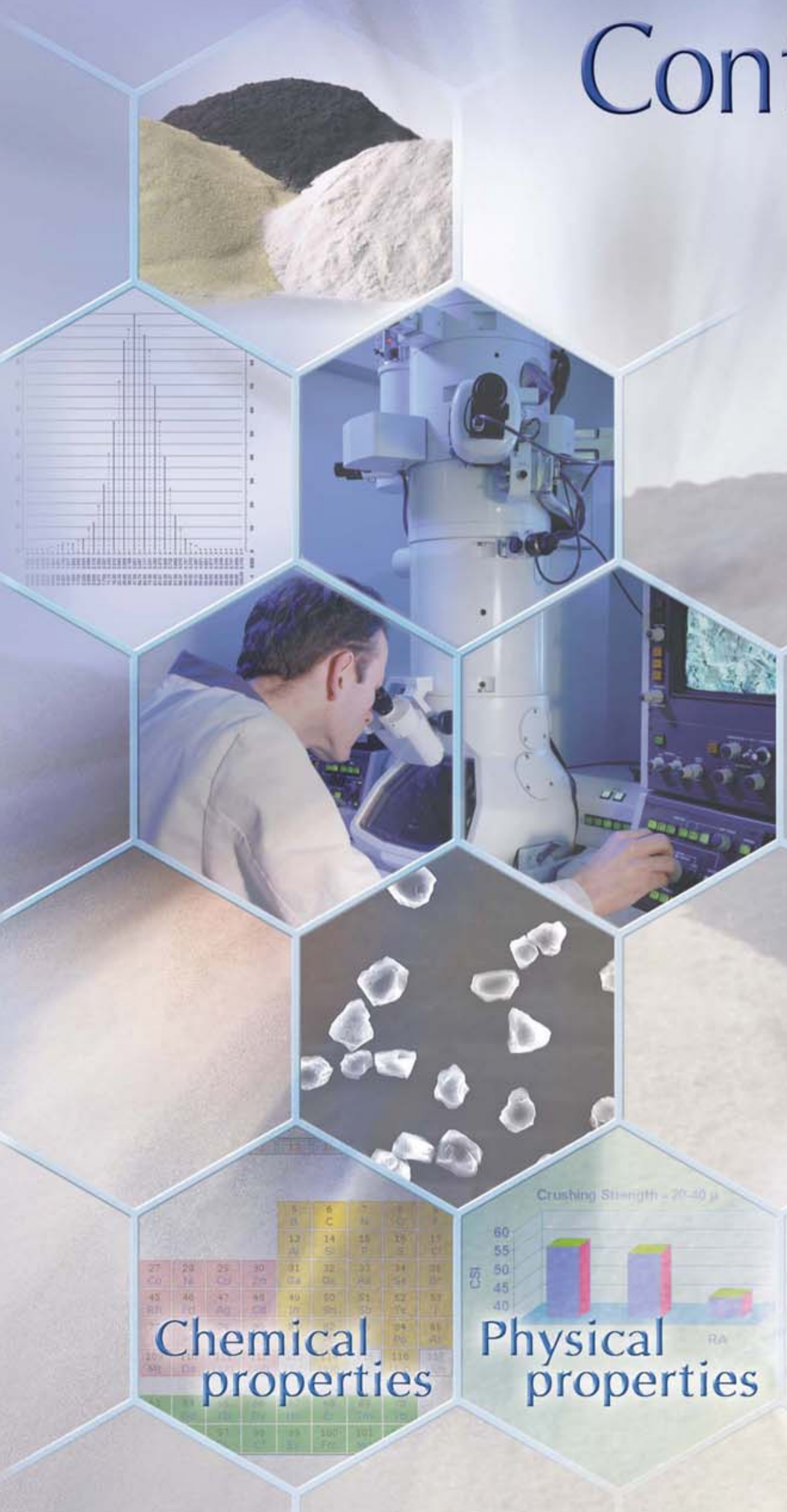

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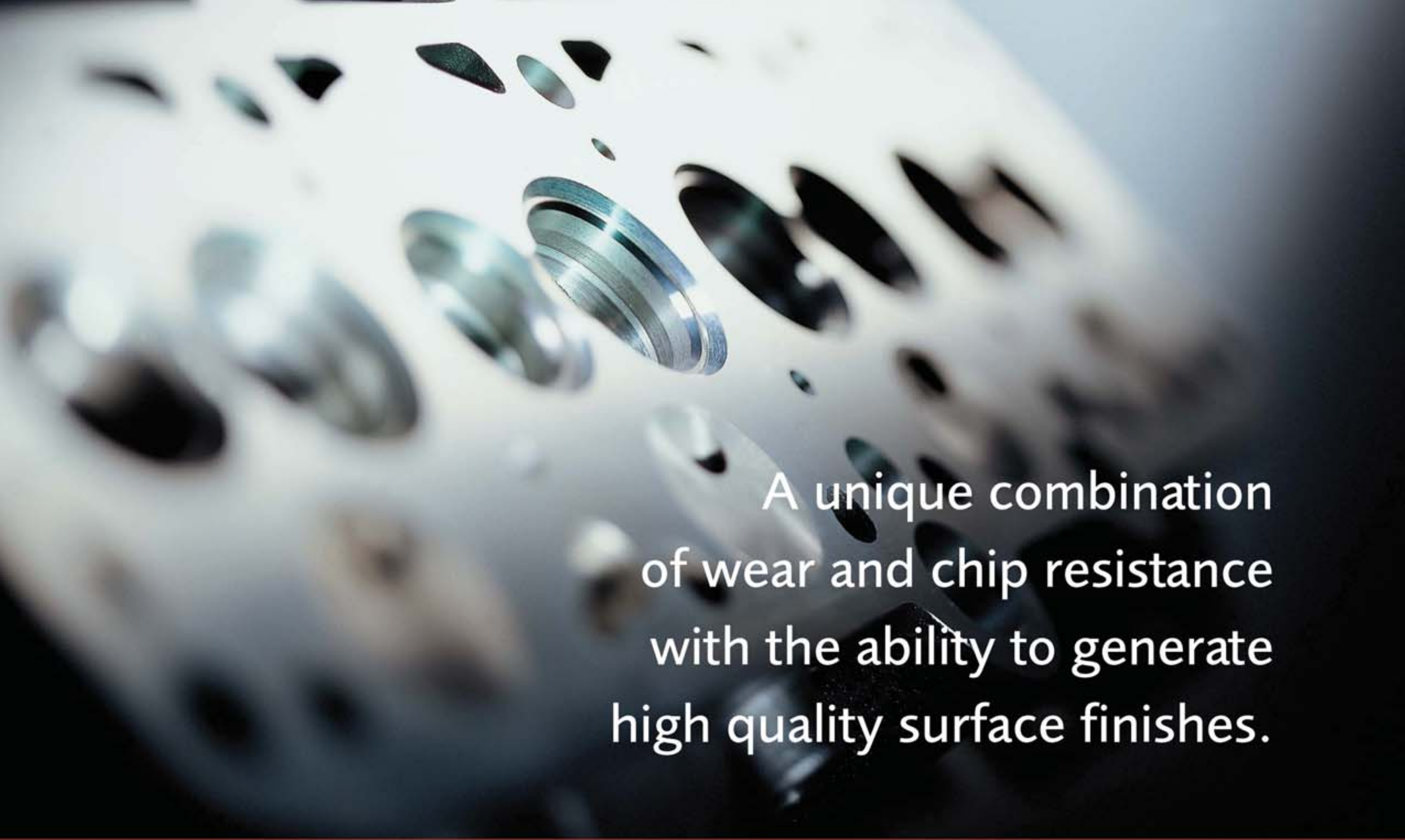
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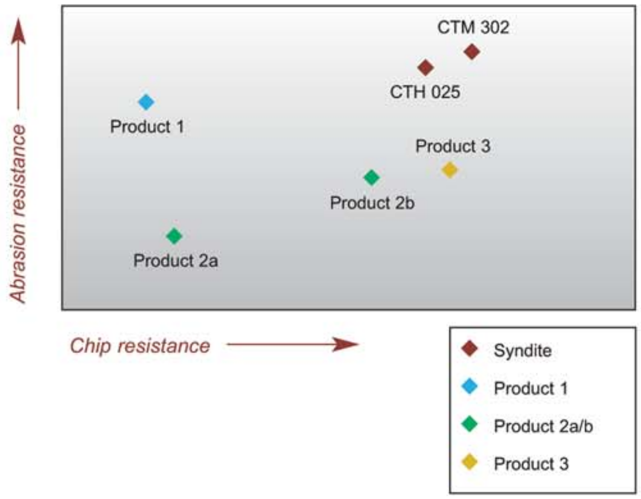

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